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EFFECTS OF THE CALCIUM-BORON RELATIONSHIP ON GROWTH AND PRODUCTION OF THE PINEAPPLE PLANT
*E. Hernández-Medina and M. A. Lugo-López* 207

A COMPARISON OF THE CANNING QUALITY OF THE RICO AND THE U.P.R. 3 SWEETPOTATOES
*F. Sánchez-Nieva, J. Bonero, and M. A. González* 224

THE RESPONSE OF HEGARI SORGHUM TO LIME APPLICATIONS AT VARIOUS LEVELS. *M. A. Lugo-López, Pablo Landrau, Jr., and B. G. Capó* 233

INFLUENCE OF NITROGENOUS FERTILIZERS ON GUINEA GRASS YIELD AND CARRYING CAPACITY IN LAJAS VALLEY
*L. Rivera-Brenes, E. N. Colón-Torres, F. Gelpí, and J. Torres-Más* 239

CONSIDERATIONS ON THE CONVENIENCE OF DISTILLING AT HIGH PROOF IN CONTINUOUS ALCOHOLIC DISTILLATION FOR BEVERAGES. . . . . *Herminio M. Brau* 248

CONTROL OF THE RED-BANDED THRIPS, *SELENOTHRIPS RUBROCINCTUS* GIARD, ON *ACALYPHA*. . . . . *Silverio Medina Guad* 258

*MYZUS PERSICAE* (SULZER) IN PUERTO RICO
*Clyde F. Smith, L. F. Martorell, and M. E. Pérez-Escolar* 263

RESEARCH NOTE
Notes on the Ecology of Coffee Plantations. . . . . *Allan F. Archer* 267

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# Effects of the Calcium-Boron Relationship on Growth and Production of the Pineapple Plant


*E. Hernández-Medina and M. A. Lugo-López*[1]


## INTRODUCTION

Work dealing with calcium-boron relationships in plant nutrition has revealed an apparent association between the calcium in the soil and the availability of boron to the plants. Naftel (*10*, *11*, *12*)[2] demonstrated that excessive liming adversely affected plant growth by bringing about boron deficiency. Cook, *et al.* (*4*) have shown that boron-deficient plants were most seriously affected where active calcium was greatest. According to Midgley, *et al.* (*9*), excessive application of liming materials such as calcium carbonate and calcium oxide, promotes boron fixation as long as they maintain the growth medium sufficiently alkaline. Wolf (*15*) found that the boron content of the crop decreased and boron deficiency occurred with increasing rates of application of hydrated lime. According to Jones *et al.* (*8*), plants grown in soils with a very high calcium content, such as alkaline or overlimed soils, required more boron than in acid soils. They pointed out that the physiological balance of calcium and boron in such soils tends to be disturbed because of the excess intake of calcium by the plants. In fact, they made the suggestion that plants growing in such soils may require more boron than is generally available.

To judge from the investigations mentioned above, metabolic disturbances of plants are likely to result in abnormal growth because of an initiation or accentuation of boron deficiency in them as a result of overliming the soil.

In Puerto Rico pineapple growers used to make lime applications to their pineapple soils every year. It appeared possible that these annual applications might accumulate in the soil to such an extent as to limit boron intake by the pineapple plant. This, in turn, could cause boron deficiency, which may probably have been reflected in low pineapple yields.


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[2] Italic Numbers in parentheses refer to Literature Cited p. 222–3.

Therefore, a greenhouse experiment was undertaken to obtain fundamental knowledge on the effects of different calcium and boron nutrient levels upon the physiology of the pineapple plant under controlled conditions. It was felt that the data from this work could serve as a basis for future research.

## MATERIALS AND METHODS

### CULTURAL METHOD

For this experiment pineapple slips of the Red Spanish variety were obtained from Palo Blanco, Arecibo, which is one of the typical pineapple areas in Puerto Rico. The slips were selected for uniformity in size and weight and were planted in purified quartz sand in 5-gallon coffee-urn liners. The average weight of the slips was 327 gm. The extreme weights among all slips fluctuated between 300 and 350 gm.

The slips received only distilled water for a period of about 3 weeks, when they were given a dilute complete nutrient solution for some 60 days, and then the differential nutrient treatments were started. The nutrient treatments were maintained until fruiting. The slop-culture technique was adopted for applying the nutrient solutions. A liter of nutrient solution was applied to each culture every other day. This was sufficient to keep the nutrient medium wet, as judged from the dripping which began a relatively short period following the application of the fresh solutions. Once a week the cultures were flushed with distilled water so as to remove any concentration of salts at the surface of the sand. This was immediately followed by application of fresh nutrient solutions.

In this experiment five calcium nutrient levels were employed, as follows: 5, 50, 100, 250, and 500 p.p.m. Five cultures were grown at each calcium level, each receiving a different boron concentration. The concentrations of boron used were as follows: 0, 0.001, 0.25, 1.0, and 5.0 p.p.m. Thus, there was a total of 25 treatments in the whole experiment and each treatment was replicated 3 times, making a total of 75 cultures. Although 5 p.p.m. boron is probably insufficient to cause much toxicity in the plants, it was assumed that it might to some extent upset the normal metabolism of the pineapple plant. The experiment was arranged following a triple-lattice design.

The nutrient solutions were prepared by using the following salts in the molar concentrations indicated:

| | |
|---|---|
| $KH_2PO_4$ | 0.00097 |
| $K_2SO_4$ | .00095 |
| $NaNO_3$ | .0071 |
| $MgSO_4$ | .0016 |

The different calcium levels were maintained as shown in the following tabulation:

| *Ca level (p.p.m.)* | *Molar concentration of salts* |
|---|---|
| 5 | 0.000125 $CaCl_2$ |
| 50 | .00125 $CaCl_2$ |
| 100 | .0025 $CaCl_2$ |
| 250 | .00625 $CaCl_2$ |
| 500 | .00625 $CaCl_2$ + 0.00625 $CaSO_4$ |

Other essential nutrient elements were supplied to all cultures expressed in p.p.m. as follows: Fe, 2.0; Mn, 0.5; Zn, 1.0; Cu, 1.0; and Al, 1.0.

Observations were made on the effect of the various calcium-boron nutrient treatments on plant growth and development. Six months after starting treatments leaf samples were taken from each plant for total and soluble calcium and boron determinations. The active or largest leaf of each plant was selected for this purpose (*14*). The meristematic tissue of the leaves was used for the analytical work. Leaf samples for chemical work were prepared as previously reported (*6*).

All plants were treated with acetylene to induce flowering. The treatment consisted in applying to the crown of the plants about 25 ml. of a solution made by dissolving 2 ounces of calcium carbide in 5 gallons of water in a closed container. The pineapple crop was harvested some 5 months after the plants received the acetylene treatment. The growth criteria considered to evaluate the effects of treatments were fruit yields, green and dry weights of plants, fresh and dry weights of roots, and number and weight of slips.

### CHEMICAL ANALYSES

The procedure followed in grinding and ashing, and extracting the cell sap from the leaf-tissue samples has been reported elsewhere (*6*). Calcium was determined according to the official micromethod of the Association of Official Agricultural Chemists (*1*). The Berger and Truog quinalizarin method was used for the boron analyses (*2*).

## RESULTS AND DISCUSSION

### PLANT DEVELOPMENT

Pineapple plants grown where boron was omitted from the culture at the lowest and three highest levels of calcium—5, 100, 250, and 500 p.p.m. in cultures 1, 3, 4, and 5, made much less vegetative growth than plants grown in cultures which received the same level of boron, but had a low level of calcium, 50 p.p.m., culture 2. The plants in this last group were rather stout and green as compared with the almost slender and light-

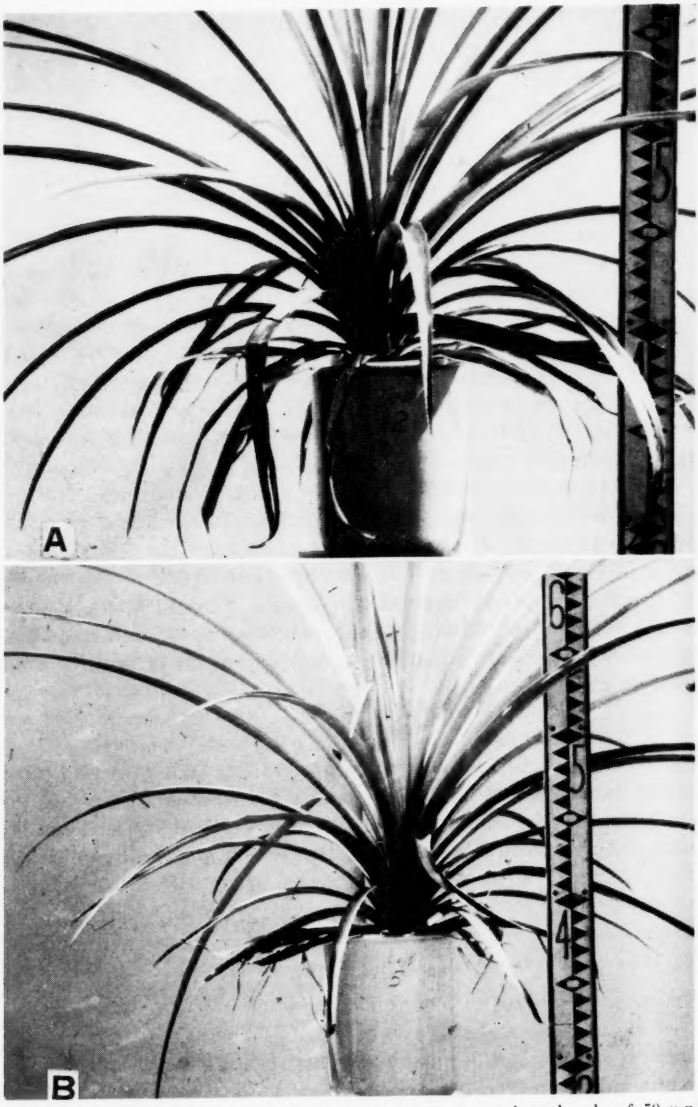


FIG. 1.—A, Pineapple plant grown in culture 2 at nutrient levels of 50 p.p.m. calcium and 0 p.p.m. boron. Plants in this treatment were rather stout and green. B, Pineapple plant grown in culture 5 at nutrient levels of 500 p.p.m. calcium and 0 boron. Plants in this treatment had a slender growth and were light green or yellow-green in color.

green or yellow-green plants of the former (fig. 1). No other differences in plant growth and development were observed which could be attributed to treatments.

### EFFECT OF CALCIUM-BORON LEVELS ON FRUIT WEIGHT

The results on mean fruit weights from plants undergoing the various calcium-boron nutrient treatments are presented in table 1 and figure 2. Statistical analyses of the yield data indicate significant differences between treatment means. Pineapple plants at the highest level of calcium, 500 p.p.m., culture 5, but without boron, produced the lowest fruit yields. On the other hand, plants grown with low and intermediate amounts of calcium, without boron, 50, 100 p.p.m. calcium, cultures 2 and 3, were the heaviest yielders. The yield of plants from culture 2 was significantly higher at the 5-percent level than that of plants from culture 5, supplied with the highest nutrient concentration of calcium but without boron in the substrate. It is evident that fruit yield was adversely affected by the high calcium concentration when boron was omitted from the nutrient medium.

Further analyses of the yield data revealed rather interesting facts concerning the highest level of boron and the various levels of calcium. At the highest boron concentration, 5 p.p.m., yields of pineapples increased with increments of the calcium concentrations. Pineapple yields were largest in those plants which received 250 and 500 p.p.m. of calcium, respectively, at the highest boron level, cultures 24 and 25. The yields of plants grown at 250 p.p.m. of calcium were significantly higher at the 5-percent level than those of plants grown at 5 p.p.m. of calcium with the same boron level, culture 21. Thus it is apparent that a combination of high calcium and high boron seems to favor a more normal metabolism in the pineapple plant than a combination of very low calcium and high boron.

At a boron level of 0.25 p.p.m., plants which received calcium in amounts of 50 and 100 p.p.m. produced significantly higher fruit yields than plants at the same boron level but the lowest, 5 p.p.m., calcium level. However, at a boron level of 1' p.p.m., plants supplied with 250 p.p.m. of calcium yielded significantly better than those at the same boron level, but at either the lowest or highest calcium concentration.

### EFFECT OF CALCIUM-BORON LEVEL ON GREEN AND DRY WEIGHT OF PLANTS

Table 1 further shows the mean green and dry weights of pineapple plants as affected by treatments. In the treatments from which boron was omitted it can be seen that the pineapple plants, culture 2, at the 50-p.p.m. calcium level produced significantly more green plant material at

the 5- or 1-percent level than those which received the two highest nutrient concentrations of calcium, but no boron, cultures 4 and 5. Thus, high

TABLE 1.—*Mean fruit weight and green and dry weight of pineapple plants grown in sand cultures at different calcium and boron concentrations in the nutrient medium*

| Culture No. | Treatment | | Mean fruit weight | Mean green weight of plants | Mean dry weight of plants |
|---|---|---|---|---|---|
| | Ca | B | | | |
| | *P.p.m.* | *P.p.m.* | *Pounds* | *Pounds* | *Pounds* |
| 1 | 5 | 0 | 2.11 | 6.02 | 0.91 |
| 2 | 50 | 0 | 2.59 | 9.59 | 1.52 |
| 3 | 100 | 0 | 2.39 | 7.74 | 1.15 |
| 4 | 250 | 0 | 2.10 | 5.64 | .90 |
| 5 | 500 | 0 | 1.69 | 6.54 | 1.11 |
| 6 | 5 | .001 | 2.58 | 7.83 | 1.18 |
| 7 | 50 | .001 | 2.37 | 7.68 | 1.09 |
| 8 | 100 | .001 | 2.58 | 8.27 | 1.25 |
| 9 | 250 | .001 | 2.22 | 6.88 | 1.07 |
| 10 | 500 | .001 | 2.38 | 8.31 | 1.22 |
| 11 | 5 | .25 | 1.86 | 4.97 | .66 |
| 12 | 50 | .25 | 2.74 | 8.06 | 1.44 |
| 13 | 100 | .25 | 2.63 | 8.99 | 1.19 |
| 14 | 250 | .25 | 2.03 | 4.61 | .73 |
| 15 | 500 | .25 | 2.54 | 6.92 | 1.11 |
| 16 | 5 | 1.0 | 1.95 | 5.19 | .79 |
| 17 | 50 | 1.0 | 2.74 | 7.28 | 1.07 |
| 18 | 100 | 1.0 | 2.75 | 9.92 | 1.53 |
| 19 | 250 | 1.0 | 3.12 | 8.55 | 1.22 |
| 20 | 500 | 1.0 | 2.31 | 8.07 | 1.28 |
| 21 | 5 | 5.0 | 2.12 | 6.71 | 1.00 |
| 22 | 50 | 5.0 | 2.35 | 6.31 | .91 |
| 23 | 100 | 5.0 | 2.35 | 7.31 | 1.09 |
| 24 | 250 | 5.0 | 3.03 | 7.12 | 1.01 |
| 25 | 500 | 5.0 | 2.80 | 6.68 | 1.02 |
| Least significant difference at: | | | | | |
| 5-percent level | | | 0.73 | 2.29 | 0.35 |
| 1-percent level | | | .98 | 3.08 | .47 |

calcium levels adversely affected the green weight of plants when no boron was supplied. Furthermore, the plants of culture 2 produced significantly more green plant material at the 1-percent level than the plants grown in

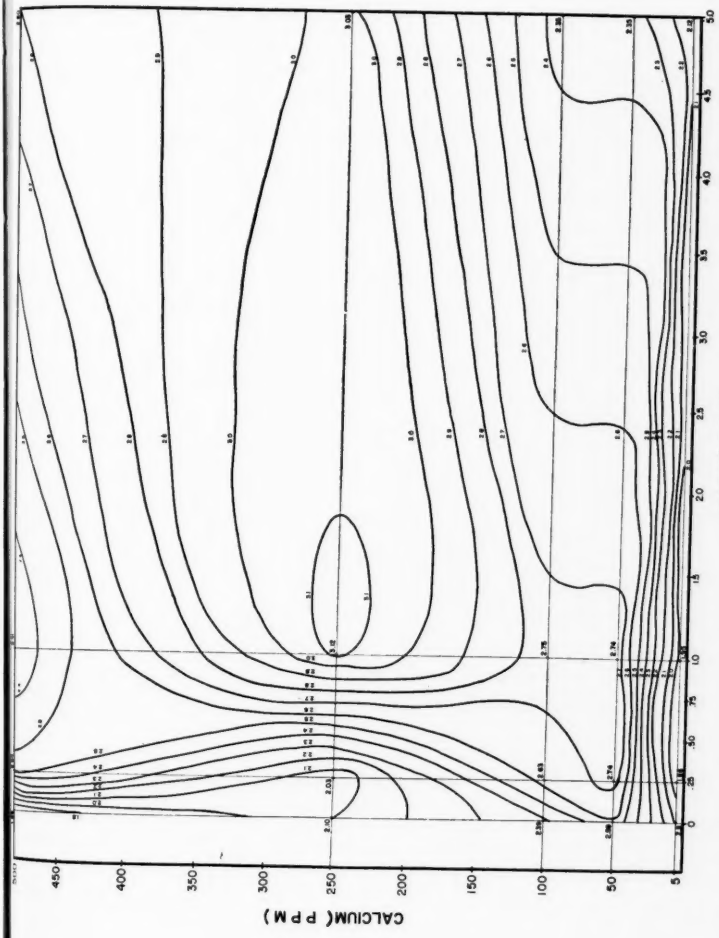


FIG. 2.—Mean fruit-weights of pineapple plants as affected by different calcium and boron concentrations in the nutrient medium.

culture 1 at the lowest calcium level, 5 p.p.m., and without boron. No significant differences were found between the green weight of plants grown at the highest boron level when the calcium was increased from 5 to 500 p.p.m. At the boron level of 0.25 p.p.m., increments in the calcium concentration induced significant differences in the green weight of plants, but the trend was not too definite. However, at the 1-p.p.m. boron level, increments in the calcium were apparently responsible for significant increases in the green weight of plants. Within any given calcium level, increases in the boron concentration did not exert any significant effect on the green weight of plants, except at 50 p.p.m. of calcium without boron, culture 2, at 5 p.p.m. of calcium and 0.001 p.p.m. of boron, culture 6, and at 250 p.p.m. of calcium and 1 p.p.m. of boron, culture 19.

The dry weight of plants in culture 2, 50 p.p.m. of calcium, from which boron was omitted, were highest of all within the group. This dry weight of the plants was significantly higher at the 1-percent level than that of plants grown at the lowest calcium level, culture 1. Increments of calcium above 50 p.p.m. with no boron reduced the dry weight of the plants as compared with those of culture 2, 50 p.p.m. calcium, and no boron. In fact, the dry weight of the latter plants was significantly higher at the 5- or 1-percent level than that of cultures 3, 4, and 5, at the highest calcium levels. Thus, at a deficient boron level, increments in calcium concentration above 50 p.p.m. reduced the dry weight of the plants. It should be recalled that the pineapple plants of culture 2 yielded best.

As in the green-weight data, no significant trend was observed in the dry weights of plants grown at the 5-p.p.m. boron level, when calcium concentrations were increased from the lowest to the highest levels. On the other hand, at the 1-p.p.m. boron level, increments in the calcium concentration caused irregular increases in the dry weight of plant material.

### EFFECT OF CALCIUM-BORON LEVEL ON FRESH AND DRY WEIGHT OF ROOTS

After fruits were harvested, the fresh and dry weights of the roots were obtained (table 2) to determine whether the nutrients had any effect on root growth and development. Plants grown at low calcium, 50 p.p.m., but without boron, culture 2, significantly surpassed all other plants in root formation, even those grown at higher calcium concentrations. Presumably, the very low concentration of calcium in the absence of boron in culture 1 limited root growth and development. As shown in table 2, increments in the calcium concentration above 50 p.p.m. reduced root development, a phenomenon most pronounced at 250 p.p.m. of calcium.

Thus, it is apparent that calcium concentrations above 50 p.p.m. adversely affected root growth when no boron was added to the nutrient medium.

TABLE 2.—*Mean weight of fresh and dry roots and number and weight of slips of pineapple plants grown in sand culture at different calcium and boron concentrations in the nutrient medium*

| Culture No. | Treatment | | Mean fresh root weight | Mean dry root weight | Mean number of slips | Mean weight of slips |
|---|---|---|---|---|---|---|
| | Ca | B | | | | |
| | *P.p.m.* | *P.p.m.* | *Grams* | *Grams* | | *Grams* |
| 1 | 5 | 0 | 209.3 | 66.2 | 0.33 | 6.67 |
| 2 | 50 | 0 | 382.9 | 96.8 | 5.33 | 214.00 |
| 3 | 100 | 0 | 226.8 | 63.1 | 1.67 | 24.00 |
| 4 | 250 | 0 | 214.9 | 52.4 | .67 | 32.33 |
| 5 | 500 | 0 | 259.2 | 68.7 | 1.33 | 21.67 |
| 6 | 5 | .001 | 246.0 | 77.8 | 1.00 | 85.33 |
| 7 | 50 | .001 | 225.8 | 66.5 | 1.33 | 21.67 |
| 8 | 100 | .001 | 256.8 | 82.7 | 1.33 | 32.33 |
| 9 | 250 | .001 | 230.6 | 59.6 | .67 | 21.33 |
| 10 | 500 | .001 | 208.0 | 64.2 | 1.33 | 28.33 |
| 11 | 5 | .25 | 176.0 | 51.9 | 0 | 0 |
| 12 | 50 | .25 | 351.0 | 85.3 | 3.67 | 5.67 |
| 13 | 100 | .25 | 220.7 | 90.1 | 1.33 | 43.00 |
| 14 | 250 | .25 | 141.0 | 51.2 | .33 | 4.00 |
| 15 | 500 | .25 | 243.0 | 66.5 | 1.33 | 22.67 |
| 16 | 5 | 1.0 | 195.7 | 55.9 | 0 | 0 |
| 17 | 50 | 1.0 | 227.9 | 64.5 | 2.33 | 112.33 |
| 18 | 100 | 1.0 | 393.9 | 83.3 | 1.67 | 106.00 |
| 19 | 250 | 1.0 | 233.4 | 68.2 | 2.67 | 110.00 |
| 20 | 500 | 1.0 | 281.9 | 62.4 | 1.67 | 66.67 |
| 21 | 5 | 5.0 | 256.5 | 70.6 | 2.67 | 67.33 |
| 22 | 50 | 5.0 | 187.5 | 71.1 | 0 | 0 |
| 23 | 100 | 5.0 | 208.8 | 57.8 | 1.00 | 19.00 |
| 24 | 250 | 5.0 | 281.5 | 74.5 | 3.00 | 137.67 |
| 25 | 500 | 5.0 | 172.7 | 52.8 | 1.33 | 29.33 |
| Least significant difference at: | | | | | | |
| 5-percent level | | | 101.46 | 27.18 | 2.70 | 152.27 |
| 1-percent level | | | 136.15 | 36.47 | 3.61 | 203.67 |

At the highest nutrient level of boron, 5 p.p.m., the fresh and dry weights of the roots did not show any definite trends with added calcium increments.

### EFFECT OF CALCIUM-BORON LEVEL ON NUMBER AND WEIGHT OF SLIPS

The plants grown at the lowest calcium level, 5 p.p.m., but without boron, culture 1, produced the lowest mean number and weight of slips within the group (table 2). No slips were produced by plants of cultures 11, 16, and 22. The lack of slip production in cultures 11 and 16 might have been caused by lack of sufficient calcium for normal metabolic processes. We have as yet no satisfactory explanation for the lack of slip production in culture 22. The mean number and weight of slips decreased significantly at the three highest nutrient levels of calcium with no boron when compared with those at the 50-p.p.m. calcium level. Both insufficient and excessive calcium, and no boron, adversely affected the production of slips by the pineapple plant.

Variations in the boron level at a given calcium concentration were responsible for significant differences in number and weight of slips in some cases, as was previously observed for the green and dry weights of plants and roots.

### CHEMICAL ANALYSES OF LEAF-TISSUE FRACTIONS

The results of the chemical determinations of total and soluble boron and calcium in the meristematic tissue of the active leaves of pineapple plants are presented in table 3. It appears that the total and soluble boron fractions, but particularly the soluble boron at a given boron level, were largely affected by the boron concentration of the substrate, and slightly influenced by the calcium concentration, with only a few marked exceptions. For instance, when boron was omitted from the nutrient solution, the soluble boron content of the meristematic tissue of active leaves of plants growing at the two highest calcium levels, 250 and 500 p.p.m., was relatively low as compared with plants growing at the three lower calcium levels (fig. 3). This suggests that soluble boron accumulating in the meristematic tissue of active leaves was affected in some way at the two highest calcium levels.

The greatest reduction of metabolically active boron occurred at the highest nutrient level of calcium, culture 5. Similar levels have been obtained by Brennan and Shive (*3*) and Hernández and Shive (*7*), working with tomato and corn plants, respectively. It should be recalled that the pineapple plants from this treatment, 500 p.p.m. of calcium and no boron, produced the lowest significant yield of pineapples when compared with the plants which received low calcium, 50 p.p.m. at the same boron level, and which yielded the most. The meristematic tissue of the active leaves of the plants from this treatment had the highest content of metabolically active boron. Thus it appears that the lowest yielding plants grown at

the lowest boron and the highest calcium level, were associated with the lowest tissue content of soluble or active boron, while the highest yielding

TABLE 3.—*Total and soluble boron and calcium contents of meristematic tissue of active leaves of pineapple plants grown in sand culture at different calcium and boron concentrations in the nutrient medium*

| Culture No. | Treatment | | Total B | Soluble B | Soluble B, percentage of total | Total Ca | Soluble Ca |
|---|---|---|---|---|---|---|---|
| | Ca | B | | | | | |
| | *P.p.m.* | *P.p.m.* | *Mg./gm.* | *Mg./gm.* | *Percent* | *Mg./gm.* | *Mg./gm.* |
| 1 | 5 | 0 | 0.018 | 0.009 | 50.0 | 2.03 | 1.33 |
| 2 | 50 | 0 | .021 | .013 | 61.9 | 3.71 | .84 |
| 3 | 100 | 0 | .020 | .009 | 45.0 | 6.08 | 1.26 |
| 4 | 250 | 0 | .018 | .005 | 27.8 | 6.72 | .74 |
| 5 | 500 | 0 | .024 | .002 | 8.3 | 9.97 | 4.12 |
| 6 | 5 | .001 | .023 | .013 | 56.6 | 1.13 | .34 |
| 7 | 50 | .001 | .024 | .015 | 62.5 | 4.05 | 2.43 |
| 8 | 100 | .001 | .024 | .015 | 62.5 | 5.45 | 2.51 |
| 9 | 250 | .001 | .019 | .008 | 42.1 | 11.90 | 6.05 |
| 10 | 500 | .001 | .035 | .014 | 40.0 | 8.79 | 1.46 |
| 11 | 5 | .25 | .020 | .016 | 30.0 | 2.45 | .60 |
| 12 | 50 | .25 | .034 | .018 | 52.9 | 3.74 | 2.00 |
| 13 | 100 | .25 | .040 | .028 | 70.0 | 6.38 | 2.27 |
| 14 | 250 | .25 | .047 | .028 | 59.6 | 8.32 | 2.04 |
| 15 | 500 | .25 | .049 | .026 | 53.1 | 9.79 | 4.35 |
| 16 | 5 | 1.0 | .049 | .024 | 49.0 | 4.80 | 3.47 |
| 17 | 50 | 1.0 | .040 | .028 | 70.0 | 7.07 | 4.80 |
| 18 | 100 | 1.0 | .039 | .031 | 79.5 | 5.59 | 1.45 |
| 19 | 250 | 1.0 | .042 | .014 | 33.3 | 9.98 | 4.80 |
| 20 | 500 | 1.0 | .047 | .027 | 57.4 | 11.90 | 6.54 |
| 21 | 5 | 5.0 | .035 | .025 | 57.1 | 1.85 | 1.24 |
| 22 | 50 | 5.0 | .044 | .024 | 54.5 | 3.77 | 1.71 |
| 23 | 100 | 5.0 | .044 | .031 | 70.5 | 5.05 | 1.17 |
| 24 | 250 | 5.0 | .045 | .015 | 33.3 | 10.00 | 8.37 |
| 25 | 500 | 5.0 | .036 | .009 | 25.5 | 8.57 | 2.92 |
| Least significant differences at: | | | | | | | |
| 5-percent level | | | 0.0026 | 0.0032 | | 0.333 | 0.141 |
| 1-percent level | | | .0034 | .0043 | | .445 | .188 |

plants were associated with the highest content of soluble active boron in the leaf-tissue fraction analyzed i.e., the plants grown at a 50-p.p.m. calcium level.

At the highest boron level increments in the calcium level did not have any marked influence on tissue content of total boron. However, soluble boron was reduced at the second highest calcium level, culture 24, and

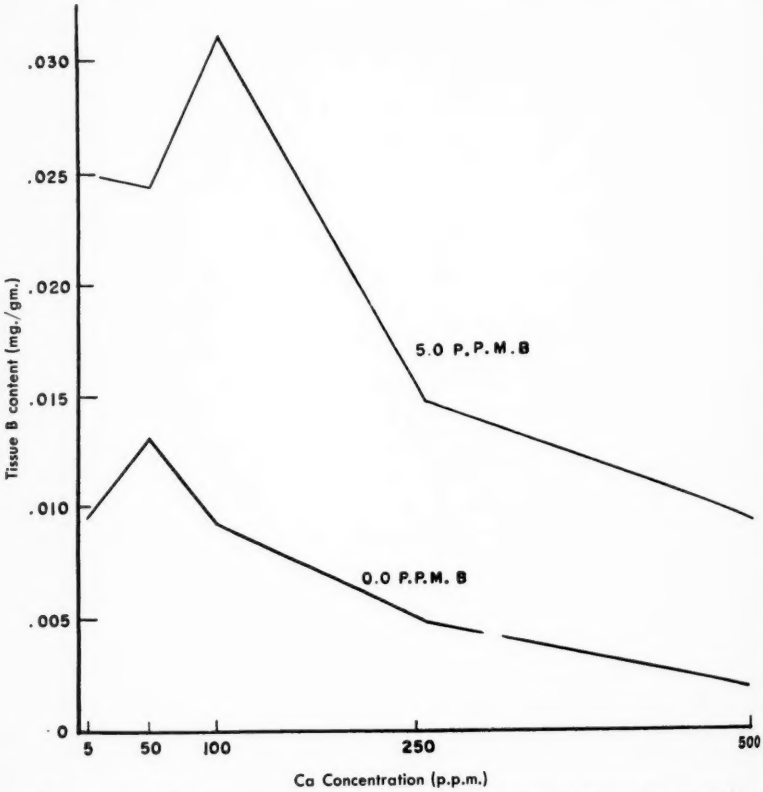


FIG. 3.—Soluble boron content of the meristematic tissue of active leaves of pineapple plants grown at 0 and 5.0 p.p.m. boron, plotted against calcium concentration in the substrate.

still more at the highest calcium level, culture 25, (fig. 3). This indicates the possibility that soluble boron might have been bound to some extent at the two highest calcium levels when boron was supplied at a high concentration in the nutrient medium. It should be recalled that the plants which received the two highest concentrations of calcium at the highest boron level produced higher yields than those which received the lowest calcium concentration at the same boron level.

In general, total calcium at any given boron level was largely determined by the calcium concentration and was not greatly influenced by the boron concentrations. With few exceptions, increments in the boron concentration did not greatly influence the total calcium content of the plant tissue at a given calcium level. On the other hand, and contrary to expectations, increments in the calcium concentration at a given boron level were not followed by a consistent increase of soluble calcium in the plant tissue, and there was no definite trend in soluble-calcium data at a given calcium level with increments of boron. As shown in table 3, soluble calcium does not seem to depend either on the total calcium or the total or soluble boron contents of the tissue.

## CONCLUSIONS

The results presented in this paper show the interrelationship of calcium and boron, and their influence on the metabolism of the pineapple plant.

The fact that the pineapple plants which received only 5 p.p.m. of calcium without boron produced more than those which received the highest nutrient concentration of calcium, 500 p.p.m., at the same boron level, suggests that the combination of high calcium and deficient boron disturbs the normal metabolism of the pineapple plant more seriously than a combination of low calcium and deficient boron.

The detrimental effect of increments of calcium above 50 p.p.m., when boron was not supplied, suggests that abnormal plant metabolism may be expected in substrates deficient in boron, when calcium is present in relatively high concentrations. It is apparent that low levels of calcium are sufficient to promote a more normal plant metabolism than high levels used with a limited or deficient boron supply.

At a boron concentration of 5 p.p.m., increments of calcium produced significantly higher fruit yields in plants which received 250 and 500 p.p.m. of calcium than in those supplied with 5 p.p.m. of calcium only. This indicates that, at relatively high boron concentrations, a combination of high calcium and high boron tends to favor a more normal plant metabolism than does very low calcium and high boron. Similar results have been obtained by other investigators (*3*, *7*, *8*), insofar as plant growth is concerned. However, no significant trends were observed in some of the other growth criteria discussed, at least at the boron and calcium levels considered.

## SUMMARY

1. The response of pineapple plants throughout their life cycle to different nutrient levels of boron in combination with different nutrient levels of calcium was studied in sand cultures.

2. Pineapple plants not receiving boron at the lowest and three highest

nutrient levels of calcium, 5, 100, 250, 500 p.p.m., made much less vegetative growth than those grown without boron, but at a low calcium level, 50 p.p.m. Plants in the last group were stout and green as compared with the rather slender and light-green or yellow-green plants of the former.

3. Pineapple plants grown without boron but at the highest calcium level produced the lowest fruit yields as compared with plants grown without boron but at low calcium, 50 p.p.m. These yielded most.

4. In pineapple plants supplied with the highest nutrient concentration of boron, 5 p.p.m., yields increased as the calcium concentration of the substrate increased from 5 to 500 p.p.m. However, yields were greatest from the plants that grew at the second highest calcium concentration, 250 p.p.m.

5. Either deficient or relatively high calcium concentrations, 5, 250, 500 p.p.m., adversely and significantly affected the green weight of plants when no boron was supplied. Low-calcium plants, 50 p.p.m., produced the highest significant green weights at the lowest nutrient level of boron.

6. Increments of calcium above 50 p.p.m. at the lowest nutrient level of boron induced significant reductions in the dry weights of plants, the weights of roots, and number and weight of slips. Deficient calcium induced a similar reduction.

7. At a given boron level, total boron in the plant tissue was largely a function of the boron concentration of the substrate and was not greatly influenced by its calcium concentration.

8. At the lowest level of boron, and at the two highest calcium levels, the content of soluble boron in the tissue was considerably less than at the three lowest calcium concentrations. The least soluble or metabolically active boron was found at the highest calcium level, while the highest content of the soluble fraction of this element was accumulated in the leaves of plants grown at low calcium, 50 p.p.m.

9. The lowest yielding plants grown without boron and at the highest level of calcium, 500 p.p.m., were associated with the lowest leaf-tissue content of soluble or active boron, while the highest yielding plants grown at the same boron level, but with low calcium, 50 p.p.m., were associated with the highest content of soluble or active boron in the meristematic tissue of the leaves.

10. Increments in the calcium level did not have any marked effect on the tissue content of total boron at the highest boron level. However, soluble boron was reduced to some extent in the tissue at the two highest calcium concentrations.

11. Plants grown at the highest level of boron and at the second highest level of calcium, 250 p.p.m., produced heavier yields than plants at the same boron level, but at either lower or higher calcium levels. However,

at the same boron level, increments in calcium did not definitely affect the green and dry weights of plants, the fresh and dry weights of roots, or the number and weights of slips.

12. Total calcium of the tissue was mainly determined by the calcium concentration of the substrate and was largely independent of the boron level. On the other hand, soluble calcium was unrelated to total calcium in the tissue, calcium in the substrate, or boron in the tissue.

## RESUMEN

1. Se informan aquí los resultados de un estudio hecho con el fin de averiguar el comportamiento de la piña, durante todo su ciclo vegetativo, a la aplicación de los elementos boro y calcio, combinadamente. Para este estudio las plantas de piña se sembraron en tiestos con arena, a los cuales se les aplicaron elementos nutritivos.

2. Las plantas de piña que no recibieron boro y estaban sembradas en medios nutritivos con la menor concentración de calcio (5 p.p.m.) y en medios con las tres concentraciones más altas de este mismo elemento (100, 250, y 500 p.p.m.) tuvieron un crecimiento vegetativo mucho menor que las plantas a las cuales tampoco se les aplicó boro, pero que se sembraron en substratos con la concentración baja de calcio (50 p.p.m.). En comparación con las plantas robustas y verdes del último grupo, las del primero se veían menos vigorosas y su color era verde pálido o amarillo verdoso.

3. El rendimiento de las plantas sembradas en medios sin boro y con la máxima concentración de calcio fué menor que el de las plantas cultivadas en medios también sin boro, pero con calcio en su concentración baja (50 p.p.m.). La producción de estas plantas fué la más alta.

4. A medida que la concentración de calcio aumentaba de 5 p.p.m. a 500 p.p.m., aumentaba también el rendimiento de las plantas que recibieron la concentración máxima de boro (5 p.p.m.). No obstante, los rendimientos más altos fueron los de las plantas sembradas en los medios que tenían la segunda cantidad más alta de calcio, o sea, 250 p.p.m.

5. Cuando faltó el boro en medios deficientes en calcio (5 p.p.m.), así como también en aquéllos con cantidades relativanente altas de este último elemento (250 y 500 p.p.m.), el peso de la materia verde de las plantas se redujo. Este peso fué más alto en las plantas cultivadas en medios con poco calcio (50 p.p.m.) y con el mínimo de boro.

6. En los medios nutritivos con la concentración mínima de boro y en los cuales la cantidad de calcio era mayor de 50 p.p.m., se verificó una disminución en el peso de la materia seca, de las raíces, de los hijos y también en el número de éstos. Los resultados fueron análogos en medios nutritivos deficientes en calcio.

7. A un determinado nivel de boro, la cantidad total de este elemento en el tejido vegetal fué mayormente una función de su concentración en el medio nutritivo y no de la cantidad de calcio.

8. Al nivel más bajo de boro y a los dos niveles más altos de calcio, el contenido de boro soluble en el tejido vegetal fué considerablemente menos que el contenido de boro soluble en las plantas sembradas a los tres niveles más bajos de calcio. La menor cantidad de boro soluble o metabólicamente activo se halló en las plantas cultivadas en los medios que tenían la concentración más alta de calcio. La fracción soluble de este elemento se acumuló en mayor cantidad en las hojas de las plantas en cuyo substrato nutritivo era baja (50 p.p.m.) la concentración de calcio.

9. El rendimiento más bajo de las plantas sembradas en medios sin boro y con la concentración máxima de calcio estuvo acompañado de la cantidad más baja de boro soluble o activo presente en el tejido foliar. En cambio, el rendimiento más alto de las plantas cultivadas al mismo nivel de boro, pero con poco calcio (50 p.p.m.), estuvo asociado al contenido más alto de boro activo o soluble en el tejido meristemático de las hojas.

10. El aumentar la concentración de calcio en medios que tenían el más alto nivel de boro no produjo efectos notables en el contenido total de boro presente en el tejido. Sin embargo, la cantidad de boro soluble disminuyó un poco en el tejido de las plantas sembradas en los medios nutritivos con las dos concentraciones más altas de calcio.

11. Las plantas sembradas al nivel máximo de boro y al segundo nivel más alto de calcio (250 p.p.m.) tuvieron mayor rendimiento que las plantas sembradas en medios con las misma cantidad de boro, pero con cantidades de calcio que eran o más bajas o más altas. No obstante, a este mismo nivel de boro, el aumento en la concentración de calcio no tuvo influencia decisiva en ninguno de los siguientes valores: peso de la materia verde y de la materia seca de las raíces, número de hijos y peso de los hijos.

12. La cantidad total de calcio en los tejidos quedó determinada, mayormente, por la concentración de calcio en el substrato nutritivo y no dependió en gran manera del nivel del boro. Por otro lado, la cantidad de calcio soluble no demostró guardar relación alguna con la cantidad total de calcio en los tejidos con la cantidad de este mismo elemento en el substrato, o con la cantidad de boro en los tejidos.

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# A Comparison of the Canning Quality of the Rico and the U.P.R. 3 Sweetpotatoes

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## INTRODUCTION

The Puerto Rican canning industry has been processing, almost exclusively, sweetpotatoes of the U.P.R. 3 variety. It has been preferred for its attractive color, good flavor, firmness, and high B carotene content. Recently, Moscoso (*1*)[2] developed a new variety of sweetpotato, the Rico, which is very similar to the U.P.R. 3, but which has the added advantage of giving higher yields. Since no information is available on the canning quality of this new variety it was decided to compare its behavior during processing, as well as the quality of the canned product, with that of the U.P.R. 3.

The canning of sweetpotatoes has been fully described by Woodroof, *et al.* (*2*)[2], who recommended a process with 13 steps: Grading, washing and preheating, peeling, washing, acid-dipping, trimming, cutting and rinsing, filling, siruping, exhausting, closing, processing, and cooling. However, a more simple process is used in commercial practice in Puerto Rico.

The sweetpotatoes, after grading, are immediately peeled in lye without preheating, and no acid dip is used after peeling. Although it is recognized that heating before peeling is convenient to inactivate the enzyme system and to prevent discoloration (*3*), and also that an acid dip should be used for similar purposes, as well as for removing traces of lye, it was decided not to use these two steps in canning the sweetpotato. This was because the objective of the tests was to compare the relative utility of the two above-mentioned varieties in the canning of sweetpotatoes in Puerto Rico, where heating before peeling and acid-dipping are not practiced commercially.

## EXPERIMENTAL PROCEDURE

The two varieties of sweetpotatoes, the U.P.R. 3 and the Rico, were obtained from the Isabela Substation. They were harvested about 4½

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[2] Italic numbers in parentheses refer to Literature Cited, p. 231–2.

months after planting, graded for size, and processed immediately. Only roots ranging in size from 1½ to 2 inches in diameter were used.

The sweetpotatoes were processed on pilot-plant scale on a line with a capacity for processing 300 pounds per hour. The roots were washed in a rotary washer and peeled in 10-percent lye at 210°F. A rotary lye-peeler similar to the one described by Thurber and Bohne was used (*4*). From the lye-peeler the roots were discharged into a rotary washer provided with high-pressure water sprays to remove lye and loose peel. Trimming immediately followed peeling and washing. The roots were kept under water before and after trimming to prevent discoloration. The processed sweetpotatoes were packed in plain tin cans with C-enamel ends of 14-oz. fill-in weight per No. 2 can. Thirty-five-degree Brix sirup at 200°F. was added and the cans were exhausted in a steam exhaust-box for 15 minutes to a center can temperature of 165°F. After closing, the cans were retorted for 45 minutes at 240°F. and cooled to 100°F. The cooled cans were air-dried and stored at room temperature.

## ANALYTICAL METHODS

### ANALYSIS OF THE UNPROCESSED ROOTS

Ten roots were selected at random and ground in a food-chopper. Individual samples were taken for moisture, starch, sugar, and B carotene determinations. This method of selection and preparation of samples has been shown to involve relatively small errors in sampling and in the chemical determinations (*5*).

For moisture determinations, duplicate samples of the ground pulp weighing about 10 gm. each were dried to constant weight in a vacuum oven at 70°C. under a vacuum of 100 mm. Loss in weight was calculated as percentage of moisture (*6*).

For determination of reducing and total sugars, 25-gm. samples of the ground pulp were transferred to 250-ml. volumetric flasks, 115 ml. of 54.3-percent alcohol were added, and the mixture was heated in a steam bath for 1 hour. After cooling, 95-percent alcohol was added to make to volume, and the mixture filtered. Two-hundred-milliliter aliquots were evaporated on a steam bath to 20–30 ml. transferred to 100 ml. volumetric flasks, saturated neutral lead acetate solution was added, and the mixture was allowed to stand 15 minutes. The solution was diluted to mark with water and filtered. The filtrate was deleaded with $Na_2CO_3$ and filtered. Reducing sugars were determined in the filtrate without inversion. Total sugars as invert were determined after inversion with hydrochloric acid. Sugars were determined by the Munson and Walker procedure (*7*).

B carotene was determined in samples of the ground pulp by the Moore and Ely procedure, but using acetone as the extractant (*8*, *9*).

Starch was determined by the method described by Carter and Neubert (*10*) for the determination of starch in apples. The standard spectrophotometric curve was prepared using a Spectronic 20 at 590 mμ.

For total-acidity determination a 10-gm. sample of the ground pulp was made into a slurry with distilled water and titrated with 0.1 N NaOH to pH 8.1 in a titrometer. Titratable acidity is expressed as percentage of anhydrous citric acid.

Color was measured in a Hunter Color and Color-Difference Meter as follows: A whole root was cut lengthwise in halves. Color was measured for the exposed flesh with the meter calibrated for $R_d$, a and b, with a white standard. Readings from several roots of the same variety were averaged.

### ANALYSIS OF THE CANNED PRODUCT

Two methods of sample preparation were tried: In one method the whole content of the can was disintegrated in a Waring blendor and samples of the slurry were taken for analysis. In the second method the liquid was drained and the drained sweetpotatoes made into a slurry in an electric blendor, and samples taken for analysis. Difference between samples in a lot was found to be so great that it was not possible to obtain reliable data for comparison purposes by either of the two methods. Therefore, no analytical data on the canned product have been included in this report.

### ORGANOLEPTIC TESTS

The quality of the canned product was determined organoleptically by trained tasters from our own staff. Two methods were used to determine product quality and preference. By one method, a sample of processed sweetpotato was presented to the tasters in an air-conditioned testing booth under red light. Tasters were required to score the samples for tenderness, fibrous condition, flavor quality, sweetness, and off-flavors. The color of the sample was similarly scored under daylight. A 5-point scale was used for all criteria measured. Average scores for each factor were calculated and the difference between samples was statistically computed.

The pair test was used in the second method. A sample of each variety was presented to the tasters under the conditions described above. The tasters were requested to taste both samples and to indicate their preference on the basis of tenderness, fiber content, flavor, color, and appearance. Differences between the samples were determined by statistical analysis of the data.

## RESULTS

### COMPOSITION OF THE UNPROCESSED ROOTS

The analytical data on samples of raw roots are given in table 1. These values represent the average of four analyses of samples of each variety.

harvested at different intervals during the season, but of approximately the same age. The Rico is higher in moisture and reducing total sugars than the U.P.R. 3, but lower in starch and B carotene. Because of the higher moisture content of the Rico variety, when results are expressed on a dry basis, as in table 2, the Rico contains more starch than the U.P.R.

TABLE 1.—*Chemical composition of raw roots of 2 sweetpotato varieties expressed on wet basis*

| Constituent or color | Rico | U.P.R. 3 |
|---|---|---|
| | *Percent* | *Percent* |
| Moisture | 70.5 | 66.4 |
| Total acidity | .14 | .14 |
| Reducing sugars | 1.23 | .59 |
| Total sugars as invert | 4.70 | 3.80 |
| Starch | 24.10 | 26.70 |
| | Mg./100 gm. | Mg./100 gm. |
| B carotene | 9.40 | 11.80 |
| Hunter color | | |
| Rd | 44.3 | 40.2 |
| a | 28.1 | 29.2 |
| b | 31.8 | 30.7 |

TABLE 2.—*Chemical composition of raw roots of 2 sweetpotato varieties expressed on dry basis*

| Constituent | Rico | U.P.R. 3 |
|---|---|---|
| | *Percent* | *Percent* |
| Reducing sugars | 4.17 | 1.76 |
| Total sugars as invert | 15.90 | 11.30 |
| Starch | 83.00 | 78.00 |
| | Mg./100 gm. | Mg./100 gm. |
| B carotene | 31.80 | 35.20 |

3. Both varieties were found similar in total acidity and pH. The color of both varieties was about the same. Small differences in the Hunter Color values in table 1 can be attributed to small difference in color between samples, as well as to variations in readings normal to the instrument.

## PROCESSING CHARACTERISTICS

### *Lye-Peeling*

Both varieties were peeled in 10-percent lye at 210°F. The time required for peeling was different for each variety. Usually a 6-minute treat-

ment was enough to peel the U.P.R. 3, while the Rico required from 8 to 10 minutes. It was repeatedly observed that the U.P.R. 3 was easier to peel than the Rico. After lye-peeling it was very easy to remove all rag and excess lye from the U.P.R. 3 by washing with water sprays in a rotary washer. The peeled root was always found to be a bright yellow free from discoloration.

It was found to be very difficult to remove the peel completely from the Rico. The sweetpotato discharged from the rotary washer was invariably found to have discolored spots resulting from an incomplete removal of peel and lye. It was necessary to wash the roots by hand before trimming in order to remove the peel completely. It was also observed that every time the Rico was processed, fibrous bundles collected at the openings of the screen of the washer, requiring frequent washing with a high-pressure hose for their removal.

Peeling losses were found higher for the Rico. As can be seen in table 3

TABLE 3.—*Percentage peeling and trimming losses, and root recovery, for raw roots of 2 sweetpotato varieties—average figures from 4 runs*

| Item | Rico | U.P.R. 3 |
|---|---|---|
| Peeling loss | 28.80 | 23.40 |
| Trimming loss | 14.40 | 14.20 |
| Recovery of roots for canning | 57.00 | 63.00 |

losses during peeling and washing were found to be 23.4 percent for the U.P.R. 3 and 28.8 for the Rico. Higher peeling losses for the Rico suggested that this variety probably had a thicker peel and cortex than U.P.R. 3, but measurement of both varieties indicated the opposite. The Rico was found to have markedly thinner peel and cortex than the U.P.R. 3. It could be established that there was a better defined cortex in the U.P.R. 3 than in the Rico. The cortex of the U.P.R. 3 could be fairly easily separated from the storage parenchyma beneath by means of a knife, which was not possible with the Rico. The difference in behavior during lye-peeling and the higher peeling losses for the Rico can thus be attributed to the fact that the cortex in this variety cannot be easily separated from the tissue beneath, even after longer treatment with lye. This results in attack by lye of the parenchyma tissue, with subsequent discoloration.

*Trimming Losses*

Trimming losses were found similar for both varieties, as shown in table 3. Although, as previously mentioned, the difficult removal of the peel in the Rico variety resulted in surface discoloration, no trimming was

necessary to remove the discolored tissue. Since only small quantities of sweetpotatoes were processed, it was an easy matter to remove this tissue by hand-washing the roots before trimming or cutting the ends. In commercial processing, however, it is expected that higher trimming losses would result with the Rico, as discolored tissue would have to be cut, since hand-washing would be impossible.

*Over-All Yields*

Higher peeling losses resulting from processing of the Rico reduced the yields of roots for canning about 6 percent when compared with yields obtained when processing the U.P.R. 3. However, since the Rico variety yielded about 3,200 pounds more per acre (*1*) than the U.P.R. 3, processing of the Rico would result in an over-all yield of 1,600 pounds of processed roots for canning in excess of that obtained with the U.P.R. 3. It should be noted that this increase in yield is expressed in terms of farm output instead of canned product. To the canner, processing of the Rico means lower yields of canned product per ton of roots processed, and therefore, the U.P.R. 3 is to be preferred. Since Rico yields better, it is suggested that the price to be paid by the canner for this variety be lower than that paid for the U.P.R. 3 in order to keep processing costs at a similar level. Otherwise canners will not benefit by processing the Rico, as no improvement in yields or quality can be expected to result when processing this variety.

*Siruping, Exhausting, and Cooking*

No difference could be observed between the two varieties during siruping, exhausting, and cooking. Neither of the two varieties was found to discolor appreciably during processing. Exhausting for 14 minutes to a can-center temperature of 160–165°F. was found adequate to insure a good vacuum in the can. Processing for 60 minutes at 240°F., as is generally recommended for Puerto Rican-type sweetpotatoes (*11*), was found detrimental to the product. When this processing time was used, both varieties became mushy and easily broke down during normal handling of the cans. All packs prepared in the course of this work were processed for 45 minutes at 240°F. Heat-penetration measurements on the canned product, as well as bacterial counts, showed this process to be safe under the conditions prevailing during the pilot-plant processing of the packs. Processing for the time indicated resulted in a better quality product.

## QUALITY OF THE CANNED PRODUCT

In table 4 are tabulated the results of the organoleptic tests when tasters were served single samples consisting of a single processed sweetpotato

from which the sirup had been drained. All samples received similar ratings for the different quality factors, irrespective of variety. Statistical analysis of the data indicated that no difference could be detected by tasters between the two varieties.

In an attempt to determine more precisely where there was a difference in the quality of the canned Rico and U.P.R. 3 sweetpotatoes, a sample of

TABLE 4.—*Quality of the canned product from 2 sweetpotato varieties as appraised on individual samples organoleptically*

| Quality criteria | U.P.R. 3 sample | | | | Rico sample | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | A′ | B′ | C′ | D′ |
| Tenderness | 4.43 | 4.38 | 4.70 | 4.20 | 4.50 | 4.47 | 2.90 | 4.70 |
| Fibrousness | 3.86 | 4.24 | 3.10 | 3.15 | 4.27 | 4.29 | 3.10 | 3.85 |
| Sweetness | 4.57 | 4.90 | 4.40 | 4.20 | 4.07 | 4.24 | 3.40 | 4.65 |
| Off-flavor | 5.00 | 4.85 | 4.90 | 4.95 | 4.67 | 4.62 | 4.60 | 5.00 |
| Appearance | 3.83 | 3.58 | 4.00 | 3.52 | 4.33 | 3.90 | 3.90 | 4.48 |
| Color | 3.71 | 4.65 | 3.70 | 3.48 | 3.46 | 3.65 | 3.70 | 3.67 |
| Flavor | 3.93 | 4.24 | 3.80 | 3.65 | 4.13 | 3.71 | 3.10 | 4.30 |
| Total score | 29.79 | 30.88 | 28.60 | 27.15 | 29.43 | 29.88 | 24.70 | 30.65 |

TABLE 5.—*Results of pair-test comparisons on canned sweetpotatoes of 2 varieties, showing percentage of tasters selecting sample for indicated quality criteria*[1]

| Quality criteria | Rico A | U.P.R. 3 A′ | Rico B | U.P.R. 3 B′ | Rico C | U.P.R. 3 C′ | Rico D | U.P.R. 3 D′ |
|---|---|---|---|---|---|---|---|---|
| More tender | 50.0 | 50.0 | 38.1 | 61.9 | 20.0 | 80.0* | 75.0* | 25.0 |
| Less fibrous | 83.3* | 16.7 | 61.9 | 38.1 | 65.0 | 35.0 | 60.0 | 40.0 |
| Better flavor | 56.6 | 46.4 | 28.6 | 71.4 | 10.0 | 90.0* | 65.0 | 35.0 |
| Better appearance | 62.4 | 37.6 | 88.2* | 11.8 | 45.0 | 55.0 | 78.0 | 22.0 |
| Better color | 62.4 | 37.6 | 82.4 | 17.6 | 50.0 | 50.0 | 100.0* | |
| Preferred | 60.0 | 40.0 | 38.1 | 61.9 | 15.0 | 85.0* | 100.0* | |

[1] * = Significant difference between samples at 5-percent level.

each variety was presented to the tasters at the same time. They were required to indicate their preference for the different quality criteria.

The results of these tests are given in table 5, in which the percentage of tasters selecting a sample is shown. Statistical analysis of the data shows that no difference could be found between samples A-A′, except for fibrousness; the Rico was chosen as less fibrous, the results being significant at the 5 percent probability level. In pair B-B′, no difference could be found except in appearance; the Rico was found better in appearance, the results being significant at the 5-percent level. In pair C-C′ the U.P.R. 3 was

found to have better flavor and to be more tender while, in pair D-D′, the Rico was preferred for better color, over-all quality, and tenderness.

Although it was possible to establish certain differences between the varieties in the pairs studied by the use of the pair test, no conclusive results were obtained to indicate that one variety was better than the other. The difference between varieties for some of the quality attributes was so small that it could hardly be detected in a pair test. It is to be expected then, that consumers would be unable to detect any difference in quality between varieties. It can be concluded that the quality of the sirup-packed sweetpotato of the Rico and U.P.R. 3 varieties is essentially the same.

## SUMMARY

The processing and canning quality of the sweetpotato varieties U.P.R. 3 and Rico was studied. Unprocessed roots of the Rico variety were found higher in moisture and sugar than the U.P.R. 3, but the U.P.R. 3 was found to contain more B carotene. Processing losses for the Rico were 6 percent higher than for the U.P.R. 3. The higher processing losses for the Rico are caused by a higher loss during lye-peeling. There was very little difference in the quality of the sirup-packed potatoes of the two varieties. Tasters were unable to establish preference in regard to over-all quality of either.

## RESUMEN

Se estudió el comportamiento de las variedades Rico y U.P.R. 3 durante el proceso de enlatado y se comparó la calidad del producto enlatado de ambas. La batata de la variedad Rico en su estado natural contiene más humedad y un porcentaje de azúcares reductoras e invertidas totales más alto que la variedad U.P.R. 3. Esta última, sin embargo, es más rica en caroteno B.

Cuando se elaboraron estas dos variedades, se pudo establecer que la variedad Rico sufre una pérdida mayor en peso al pelarse con soda que la variedad U.P.R. 3. El rendimento de batata elaborada por quintal de batata fresca fué 6 por ciento mayor en cuanto a la variedad U.P.R. 3.

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# The Response of Hegari Sorghum to Lime Applications at Various Levels

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## INTRODUCTION

The application of lime to acid soils brings about changes in the conditions of the soil that generally result in improving the yield of some crops. The correction of the soil reaction, as such, is one of the physiological factors involved. Other soil conditions affected include the supply of exchangeable calcium and magnesium; the availability of phosphorus; the solubility of iron, manganese, and other elements; soil structure; and the activity of the soil microorganisms.

In Puerto Rico, where more than half of the total acreage consists of acid soils, the proper use of lime is of paramount importance. May (*6*)[2] obtained response in sugarcane yields following liming of the soil. McClelland (*7*) and subsequently other investigators (*5*) failed to obtain increases in coffee yield attributable to liming. Bonnet, *et al.* (*2, 3*) measured increases in the yield of several legumes grown for green manure and of sweetpotatoes and corn. They also obtained responses to liming from various grasses when grown in association with a legume (*1*). Pennock (*8*) has reported on the influence of lime applications on pineapple growth and production.

This paper presents data obtained from a greenhouse experiment wherein the influence of various lime levels upon a crop of Hegari sorghum was measured.

## EARLIER WORK

In 1937, Capó (*4*) made extensive pot tests in a detailed study of the available nutrient contents of Puerto Rican soils, using Hegari sorghum as an indicator plant. In many of the tests with very acid soils no apparent logical yield responses were obtained to increased nitrogen, phosphoric acid, and potash applications. This abnormal behavior suggested some possible physiological imbalance, the correction of which was attempted by using lime. Table 1 shows the effect of liming on sorghum dry-matter yields as measured in Capó's greenhouse experiments. Marked statistically significant beneficial effects were measured in strongly acid soil samples

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[2] Italic numbers in parentheses refer to Literature Cited, p. 238.

TABLE 1.—*Effect of liming soils on sorghum yields*[1]

| Soil type | Limestone applied | Dry matter per pot |
|---|---|---|
| | *Cwt. per A.* | *Grams* |
| Río Piedras clay | 0 | 6.6 |
| | 10 | 31.8 |
| | 20 | 34.8 |
| Moca silty clay loam | 0 | 13.2 |
| | 15 | 36.0 |
| | 30 | 58.0 |
| Cialitos clay | 0 | 17.4 |
| | 15 | 43.4 |
| | 30 | 41.4 |
| Catalina clay, level phase | 0 | 28.5 |
| | 15 | 45.7 |
| | 30 | 38.4 |
| Vega Alta sandy loam | 0 | 34.8 |
| | 15 | 46.4 |
| | 30 | 31.4 |
| Los Guineos clay | 0 | 23.5 |
| | 15 | 40.2 |
| | 30 | 46.8 |
| Coloso clay | 0 | 24.5 |
| | 15 | 41.0 |
| | 30 | 42.3 |
| Coloso silt loam | 0 | 40.9 |
| | 15 | 39.0 |
| | 30 | 44.4 |
| Estación silt loam | 0 | 57.2 |
| | 10 | 54.1 |
| | 20 | 53.2 |
| Lares clay | 0 | 55.9 |
| | 15 | 51.0 |
| | 30 | 49.0 |
| Múcara silty clay loam | 0 | 41.5 |
| | 15 | 46.4 |
| | 30 | 44.8 |
| Ciales clay loam | 0 | 39.8 |
| | 15 | 43.6 |
| | 30 | 36.6 |
| Toa silty clay loam | 0 | 35.1 |
| | 15 | 41.3 |
| | 30 | 36.2 |
| Nipe clay | 0 | 36.1 |
| | 15 | 24.8 |
| | 30 | 10.2 |
| Cabo Rojo clay | 0 | 25.4 |
| | 13 | 24.8 |
| | 26 | 26.6 |
| Mabí clay | 0 | 51.8 |
| | 13 | 53.2 |
| | 26 | 46.4 |

[1] Adapted from Capó, B. G. (4).

from Río Piedras clay, Moca silty clay loam, Cialitos clay, Los Guineos clay, and Coloso clay. No response was obtained in other less acid soil samples from Coloso silt loam, Estación silt loam, Lares clay, Ciales clay loam, Toa silty clay, Múcara silty clay loam, Jayuya silty clay loam, Cabo Rojo clay, and Mabí clay. In some soils like Nipe clay the use of lime even depressed sorghum yields. The results from this work led to the study herein reported where six lime levels were tested on a very acid soil from the northern area of Puerto Rico.

## MATERIALS AND METHODS

A greenhouse pot experiment was conducted with Fajardo clay, an acid soil with a moderate degree of buffering. The soil was collected from the plow layer at a site that has been under clean cultivation for several years, but which had not been limed previously. Nine pounds of air-dried soil screened through a ¼-inch sieve were thoroughly mixed with 4½ pounds of very fine sand and used in filling Mitscherlich pots. The pH of the soil at the time was 4.35. Six treatments were tested by using ground limestone at the rates indicated in the following tabulation:

| *Treatment identification No.* | *Rate of limestone applications in tons per A.* | *Expected pH* |
|---|---|---|
| 1 | 0.7 | 4.5 |
| 2 | 2.2 | 5.0 |
| 3 | 4.2 | 5.5 |
| 4 | 5.8 | 6.0 |
| 5 | 7.2 | 6.5 |
| 6 | 9.2 | 7.0 |

Each treatment was replicated 12 times, including a total of 72 pots in the study. The calcium carbonate equivalent of the limestone used was 99.14 percent. The lime needed was computed on basis of the 9 pounds of soil, disregarding the sand which was used to insure adequate soil aeration and water movement. An application of the three major fertilizer elements was made to the soil in each pot. The quantities of fertilizer used were as follows: 225 pounds of nitrogen (as $NH_3$), 75 pounds of phosphoric acid, and 225 pounds of potash, per acre, in each case.

Thirty-seven pregerminated seeds of Hegari sorghum were planted in each pot. Water was added at frequent intervals in an attempt to maintain the soil moisture at field capacity. In order to provide as uniform an environment as possible to each of the replicates the position of the tables where the 12 pots of each replication were placed was changed every other day. A light attack of the fall armyworm (*Laphygma frugiperda*) appeared some 19 days after seeding. The insect was controlled by spraying with a 1-percent solution of DDT. Forty days after seeding, when the plants were

nearly ready for harvest, they were attacked by *Aphis maidis*, which was quickly controlled with a spray of chlordane at a 0.5-percent concentration. The sorghum plants were harvested after 49 days of growth. They were weighed and their moisture content determined. Counts were made of the number of plants in bloom in each pot.

## RESULTS AND DISCUSSION

Data on the mean green- and dry-weight yields of sorghum are given in table 2. Information is also given as to the mean number of plants in bloom. Sorghum plants growing in soil receiving lime at the rate of only 0.7 ton to the acre yielded least. Throughout the course of the experiment these

TABLE 2.—*Mean yields and number of plants in bloom of Hegari sorghum grown in soil receiving different quantities of lime*

| Limestone applied (t./A.) | Green matter per pot | Dry matter per pot | Plants in bloom |
|---|---|---|---|
| | *Grams* | *Grams* | *Number* |
| 0.7 | 137 | 25.0 | 2.3 |
| 2.2 | 236 | 44.0 | 8.7 |
| 4.2 | 267 | 51.4 | 8.8 |
| 5.8 | 257 | 48.6 | 8.9 |
| 7.2 | 244 | 44.5 | 7.7 |
| 9.2 | 232 | 43.0 | 8.5 |
| L.S.D. at the 5-percent level | 22.8 | 8.9 | 2.2 |
| L.S.D. at the 1-percent level | 30.4 | 11.8 | 2.9 |

plants were always shorter and their leaves were of a light-green color with slightly yellowish tints. The mean differences in green-matter yield of sorghum in the soil receiving lime at the rate of 0.7 ton to the acre and each of the other treatments were highly significant. Furthermore, the green-matter production in the soil receiving 4.2 tons of lime to the acre was significantly higher than that from soils receiving either lesser amounts, or receiving lime at the rate of 9.2 tons to the acre.

There were highly significant differences between the dry matter produced by the sorghum grown in soil receiving lime at the rate of 0.7 ton to the acre and all other treatments. The extreme low lime treatment yielded least, but no significant differences were measured between any of the other treatments.

Table 2 further shows that liming influences significantly the blooming interval of the sorghum plant. In the extreme low lime treatment only about 2 plants on the average were able to bloom at 49 days of age while over 8

plants had bloomed in each of the other lime treatments and extremes of 10 or 11 were recorded in some cases. The results obtained from this work are in line with those obtained by Capó (*4*) in 1937, when growing Hegari sorghum on very acid soils to which no lime had been added.

In general, the production of Hegari sorghum in very acid soils can be increased by liming up to a pH of about 5.0. In soils with moderately low exchange capacity and a pH of around 4.35, these increases can be brought about by applying a little over 2 tons of limestone. For the sorghum crops further applications of lime beyond that point are of rather doubtful value since they do not influence significantly the growth and dry-matter production of sorghum.

It might be well to emphasize that both soil and crop must be considered jointly in determining lime needs. Field tests by Bonnet, *et al.* (*1*, *2*, *3*) in the same Fajardo clay used in this experiment, have shown response in several legumes, sweetpotatoes, corn, and soilage grasses, to higher lime levels than those herein reported and obtained with Hegari sorghum under greenhouse conditions. When dealing with some crops like sorghum and with soils like Fajardo clay at a pH of less than 4.5 the application of lime in excess of 2 tons or so may result in waste of money and effort.

## SUMMARY

A greenhouse investigation was conducted to determine the influence of various lime levels on the growth and yields of Hegari sorghum. Green-matter yields of sorghum grown in soils receiving slightly over 4 tons of limestone to the acre were significantly higher than that from the soils receiving only 0.7 ton per acre, or receiving lime at the rate of 9.2 ton to the acre. The extreme low lime treatment, 0.7 ton to the acre, resulted in significantly lower dry-matter production, but no significant differences were measured between treatments ranging from 2.2 to 9.2 tons of lime to the acre. Liming influences significantly the blooming period of the sorghum plant.

## RESUMEN

Se informan en este trabajo los resultados de una investigación hecha en el invernadero con él propósito de determinar el efecto de varios niveles de cal en el suelo sobre la producción del sorgo Hegari. Los rendimientos de materia verde en suelos que recibieron cal, a razón de poco más de 4 toneladas por acre, fueron significativamente más altos que los del suelo que recibió la cantidad menor de cal (a razón de 0.7 tonelada por acre), sin embargo, no se pudieron medir diferencias significativas entre los promedios de los demás niveles de cal que fluctuaron entre 2.2 y 9.2 toneladas por acre. El encalado afecta significativamente la época de florecida del sorgo.

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# Influence of Nitrogenous Fertilizers on Guinea Grass Yield and Carrying Capacity in Lajas Valley

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## INTRODUCTION

The Lajas Valley is a semiarid section in the southwestern corner of Puerto Rico. The arable land comprises around 35,000 acres, of which around two-thirds are dedicated to cattle raising, especially dairy cattle. Of the land in pasture only one-third is improved and cultivated pasture (*2*).[2]

Guinea grass, *Panicum maximum*, is the most important grass in the area. It is very resistant to the dry conditions prevailing and produces an abundance of good palatable roughage.

Generally speaking, pasture management is poor in the Valley. The prevailing climatic conditions are blamed for this neglect. Guinea grass is seeded once and from there on very little care is given. Fertilization is seldom practiced, as many farmers do not believe that fertilizer applications are profitable. Continuous grazing is the only system; overstocking and overgrazing are seen everywhere.

The weed problem is serious in the Valley. Pajón, *Andropogon annuatus*, is the predominant weed, which, together with paragüita, *Chloris inflata*, and other weeds, competes favorably in the field with Guinea. When Guinea grass is neglected, as indicated above, these weeds take over and eliminate it in a very short time. Some farmers claim, though, that Pajón is a good pasture grass which can withstand the most severe drought and treatment, being in this respect better than Guinea grass.

Actually the Government of the Commonwealth is establishing an irrigation district for the Valley. The district will cover more than 20,000 acres and a very drastic change in the agricultural pattern of the Valley lands is expected in a short time.

With the establishment of the Lajas Substation in Lajas Valley, research on animal husbandry and on pasture improvement and evaluation for the area were started. As Guinea grass has been the most important prevailing forage in the region, it was decided to seek information on its performance under different management conditions. Some final and some preliminary results are presented in this paper. This is the final report for

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[2] Italic numbers in parentheses refer to Literature Cited, p. 247.

Guinea grass fertilized with 200 pounds of ammonium sulfate applied per acre every 4 months, and for nonfertilized Guinea grass. It also presents a preliminary report on Guinea grass fertilized with 400 pounds of ammonium sulfate every 4 months, for which data are available for only 2 years.

## LITERATURE REVIEW

Boneta (*1*) studied the adaptability to different regions of the Island of several new strains of Guinea grass developed by the Plant Breeding Department of this Station.

Carrying capacity, as well as pounds of beef per acre, were determined for Guinea grass under different fertilizer treatments and rotational grazing in the northern humid section of the Island (*3*, *4*, *5*).

Results of the grazing trials with Guinea grass not fertilized at Río Piedras, where rainfall is over 60 inches a year, showed a carrying capacity of 0.42. The net gain in weight per acre per year was 185 pounds, plus the equivalent of 626 pounds of TDN from the residue clipped per acre. Further grazing trials in which Guinea grass received an initial application of 1,000 pounds of 10-10-5, and 200 pounds of ammonium sulfate every 4 months thereafter raised the carrying capacity to 0.9. The net gain in weight per acre per year was 515 pounds, plus the equivalent of 2,132 pounds of TDN from the residues clipped per acre.

Guinea grass has been submitted to further grazing experiments, but in combination with tropical kudzu (*4*, *5*, *7*). Results of the grass-legume combination have been very satisfactory, a carrying capacity of 1.42 having been obtained with an average net gain in weight per year of 930 pounds per acre.

Yield per acre as soilage at different cutting intervals has been also determined at Río Piedras (*6*). The yields per acre per year at 40-, 90-, and 120-day cutting intervals were as follows: 10, 7, and 7 tons of dry matter, respectively.

## PROCEDURE

The procedure followed in this study was similar to that used for previous experiments performed at the Main Station (*3*). The trial consisted originally in the comparison of three treatments with Guinea grass: First, the combination of Guinea grass with tropical kudzu; second, Guinea grass fertilized with 200 pounds of ammonium sulfate (40 pounds of nitrogen) every 4 months; and third, Guinea grass with no fertilizer at all.

The field was seeded to Guinea grass by the end of the year 1951. The kudzu was planted in the corresponding plots. A very good grass stand was obtained, but the first treatment was eliminated after the impossibility of establishing the legume. Two years after the experiment was

started, another treatment was introduced. This consisted of applications of 400 pounds of ammonium sulfate (80 pounds of nitrogen) per acre every 4 months to the plots corresponding to the grass-legume combination.

Difficulties with legume had been expected, as the findings of Telford (*8*) at Mayagüez were known beforehand; he was not able to grow kudzu successfully in places with less than 50 inches of rainfall. The combination was tried at Lajas, however, since Lajas is in that borderline. The experiment was established in a Santa Isabel clay soil, which is representative of the Valley, with no irrigation.

Eight- to twelve-month-old crossbred dairy Holstein X Native and Brown Swiss X Native heifers were used. The groups were balanced as to age, total weight, and breed. Occasionally some Guernsey heifers were used, distributed evenly among the groups.

The put-and-take system was followed, so that all roughage was consumed by the animals. In what follows the treatments will be referred to as G. 400, G. 200, and G. 0.

TABLE 1.—*Net gain in weight of animals, in pounds per acre per year, for Guinea grass under the three fertilizer treatments*

| Treatment | First year | Second year | Third year | Fourth year |
|---|---|---|---|---|
| G. 0 | 197 | 336 | 522 | 308 |
| G. 200 | 407 | 507 | 569 | 635 |
| G. 400 | — | — | 770 | 816 |

## RESULTS AND DISCUSSION

Table 1 presents the gains in weight per acre per year for the animals on the Guinea grass under the three fertilizer treatments.

The statistical analyses were made considering the differences between treatments, between years, and the interaction of years and treatments. A separate analysis was made for the last 2 years of G. 0 and G. 200 because there was a species shift during those two years in the treatment G. 0 from Guinea grass to Pajón (*Andropogon annuatus*) of over 90 percent.

The 4-year average gains in weight of the animals, in pounds, for the G. 0 and G. 200 treatments are presented in the following tabulation:

| *Treatment* | *Mean gain in weight* |
|---|---|
| G. 0 | 341 |
| G. 200 | 530 |
| L. S. D. 0.05 | 35 |
| L. S. D. 0.01 | 49 |

G. 200 was superior to G. 0 in the 4-year trial. Differences were highly significant.

The differences between grass-years, table 1, were also highly significant. The least significant differences were 69 and 97 pounds for the 5- and 1-percent levels, respectively. The last 2 years were significantly better than the first two for both treatments.

On comparing the first two years with the last two years of treatment G. 0 the possibility suggested itself that the Pajón might have performed better than the Guinea grass with no nitrogen, but after the data were analyzed the difference had to be attributed to an effect of year. The same situation was found in treatment G. 200. This is more clearly seen when the average animal gain in weight per acre per year for the two treatments together is analyzed in the following tabulation:

| *Year* | *Grain in weight in pounds per acre per year* |
|---|---|
| 1st | 302 |
| 2d | 422 |
| 3d | 546 |
| 4th | 471 |
| L. S. D. 0.05 | 49 |
| L. S. D. 0.01 | 69 |

The first 2 years of treatment G. 400 were the last for treatments G. 0 and G. 200. Separate statistical analyses were made for this period.

The following tabulation shows the mean animal gain in weight for the three treatments per acre per year:

| *Year* | *3-treatment mean in pounds per acre per year* |
|---|---|
| 3d | 620 |
| 4th | 586 |
| L. S. D. 0.05 | 72 |

The difference was not significant. The effect of year was the same for all treatments.

The difference between treatments was highly significant, as shown in the following tabulation giving the mean animal gains in weight for the third and fourth years:

| *Treatment* | *Gain in weight* |
|---|---|
| G. 400 | 794 |
| G. 200 | 602 |
| G. 0 | 415 |
| L. S. D. 0.05 | 88 |
| L. S. D. 0.01 | 134 |

Guinea grass with 400 pounds of ammonium sulfate per acre every 4 months (G. 400) was significantly superior to the application of 200 pounds

of the same fertilizer at the same intervals (G. 200). Guinea with no fertilizer (G. 0) was the lowest in yield. In the last 2 years of treatment G. 0 the plots were over 90-percent Pajón. If we point out here that this grass is considered by many farmers as a very poor weed, the gains in weight obtained per acre are really surprising and revealing. It should also be noted that the species shift in the zero-fertilizer treatment was over 90 percent while in the fertilized plots the invasion of other grasses and weeds was not over 10 to 15 percent, as calculated by inspection, considering all plots. Fertilization favored the stand of Guinea grass, not counting other beneficial effects to the soil itself.

The summary of the grazing results is presented in table 2. It includes the 4 years of G. 200, G. 0, and 2 years of G. 400.

The chemical analyses of the grass samples representing the three treatments are given in table 3. Although these analyses present some differences, they are not large enough to show the real differences between

TABLE 2.—*Grazing results for the different Guinea grass treatments*

| Treatment | Days in treatment | Standard cow-days | Carrying capacity | Heifers per acre per day | TDN per day per acre | Heifer-days | Gain in weight per acre per year |
|---|---|---|---|---|---|---|---|
| | *Number* | | *Units* | *Number* | | *Number* | *Pounds* |
| 2 years, G. 400 | 582 | 694.48 | 1.19 | 2.553 | 19.09 | 1,485 | 793.80 |
| 4 years, G. 200 | 1,193 | 998.97 | .837 | 1.899 | 13.40 | 2,267 | 529.67 |
| 4 years, G. 0 | 1,193 | 665.17 | .558 | 1.459 | 8.92 | 1,741 | 341.00 |

the treatments. The samples were taken monthly and most of the time the known boosting effect of nitrogen fertilization on protein content, had passed. Of course, the effect of the fertilizer on yields may be clearly seen in table 2.

The average rotational intervals were as follows: For the first year, 10 days; for the second, 9; for the third, 9.4; and for the fourth year 6.5 days. Rotations were made as judged convenient to prevent overgrazing.

Lajas Valley is not as dry as is commonly believed. People speak of 35 inches of rainfall a year or less. It is true that once every 10 to 15 years there is a very prolonged dry spell, but normally in the Valley the rainfall is sufficient for pasture grasses with only one or two really dry months. This may be seen in table 4, presenting the rainfall data from 1952 to 1956.

No wind data for the experimental period are available, but the region is quite windy. An almost constant dry wind blows over it which might be responsible for a high rate of evaporation. This is a factor that should be considered in further research.

The returns above cost of fertilizer and the comparison between treatments give a much better idea of the importance of fertilization. This

TABLE 3.—*Percentage chemical analyses of Guinea grass under the experimental treatments*

| Treatment | Year | Samples | Protein | Ash | Fat | Fiber | N.F.C. |
|---|---|---|---|---|---|---|---|
| G. 0 | 1953 | 14 | 6.89 | 11.67 | 1.61 | 30.34 | 49.49 |
| | 1954 | 14 | 7.47 | 12.87 | 1.50 | 27.90 | 49.82 |
| | 1955 | 6[1] | 7.31 | 11.85 | 1.67 | 31.15 | 48.02 |
| | 1956 | 3[2] | 10.69 | 11.99 | 2.14 | 29.19 | 45.99 |
| G. 200 | 1953 | 15 | 5.96 | 11.29 | 1.33 | 32.55 | 49.02 |
| | 1954 | 15 | 10.45 | 12.37 | 1.67 | 26.81 | 49.99 |
| | 1955 | 6[1] | 9.07 | 11.53 | 1.78 | 30.39 | 47.23 |
| | 1956 | 6[1] | 12.37 | 12.43 | 2.34 | 28.37 | 44.49 |
| G. 400 | 1955 | 6[1] | 12.47 | 10.91 | 1.98 | 29.71 | 44.93 |
| | 1956 | 6[1] | 13.78 | 11.40 | 2.33 | 29.21 | 43.28 |

[1] Each one of these 6 samples represents a composite sample of 4 or 5 monthly samples per block.

[2] Each sample is a composite of all monthly samples for each block.

TABLE 4.—*Rainfall data for Lajas Valley, in inches, by year and month, 1952–56*[1]

| Month | 1952 | 1953 | 1954 | 1955 | 1956 |
|---|---|---|---|---|---|
| January | 1.10 | 1.48 | 3.44 | 0.45 | 4.19 |
| February | 2.06 | .95 | 4.84 | 1.28 | .24 |
| March | 1.96 | 4.28 | 1.53 | 2.53 | 2.88 |
| April | 4.57 | 2.14 | 9.19 | 2.01 | 4.83 |
| May | 2.45 | 2.71 | 2.81 | 5.24 | 4.56 |
| June | 1.19 | 5.44 | 3.09 | 3.37 | 5.28 |
| July | 2.68 | 4.79 | 3.51 | 5.81 | 4.14 |
| August | 5.39 | 8.58 | 7.16 | 6.09 | 3.62 |
| September | 14.90 | 2.81 | 10.22 | 9.20 | 3.59 |
| October | 5.99 | 6.10 | 6.60 | 6.16 | 10.45 |
| November | 3.40 | 5.56 | 3.97 | 4.10 | 6.08 |
| December | 1.03 | 2.39 | 2.94 | 3.12 | 3.38 |
| Total | 46.72 | 47.21 | 58.30 | 51.36 | 58.44 |

[1] Data taken from the Lajas Substation records.

management practice is seldom used in Lajas Valley. The only reason given is that fertilizer is not used efficiently during the prolonged dry periods prevailing in the region. This assumption, as shown here, is unwarranted.

At 16 cents a pound of meat on hoof, the gross returns per acre per year were as follows: G. 0, $56.56; G. 200, $84.80; G. 400, $127.

Fertilizer cost per acre per year for G. 200 was $21 and for G. 400, $42. This includes cost of application. The return above cost of fertilizer was $63.80 for G. 200 and $85 for G. 400. When G. 0 and G. 200 were compared as with returns above cost of fertilizer, the difference was of only $9.34, while between G. 400 and G. 0 the excess return was $34.44.

Not counting the beneficial effects of fertilization on the soil and plant, respectively, apparently 200 pounds of ammonium sulfate per acre per year is not enough to bring a satisfactory return under the conditions under which the experiment developed.

## SUMMARY AND CONCLUSIONS

The Lajas Valley is a semiarid region located in the southwestern corner of the Island. Annual rainfall fluctuates from 40 to 60 inches with rather prolonged dry spells.

Guinea grass is the prevailing and most important pasture forage. Very little or no fertilizer at all is used and, generally speaking, the grazing management is poor.

In 1952, an experiment was started with Guinea grass submitted to different fertilizer treatments, under rotational grazing. A randomized-block design already described in another paper (*3*) was used and each treatment of 0, 40, and 80 pounds of nitrogen per acre was applied as ammonium sulfate every 4 months was replicated three times. Results obtained indicate that fertilization pays even in this relatively dry section of the Island.

The average gains in weight per acre per year were as follows: 794 pounds for the 400-pound ammonium sulfate treatment, 530 pounds for the 200, and 341 pounds for the zero-fertilizer treatment. The mean carrying capacities were 1.19, 0.84, and 0.56 adult head per acre, respectively. Rotational intervals ranged from 6.5 to 10 days throughout the 4 years of the experiment. The above-mentioned differences of gains in weight were statistically significant at the 1-percent level.

The returns above cost of fertilizer per acre were as follows: $85 for the 400-pound treatment, $63.80 for the 200, and $56.56 for the zero-fertilizer treatment. According to these figures, 200 pounds of ammonium sulfate per acre every 4 months is not enough to bring a satisfactory return, since it produced a gross return of only $9.34 as compared to zero nitrogen. The 400-pound treatment brought a gross return of $34.44 above that of the zero fertilizer treatment.

Fertilization favors the Guinea grass stands, permitting only a relatively slight competition from weeds. However, the weed Pajón, *Andro-*

*pogon annuatus*, invaded the zero-fertilizer plots severely, to the extent that for the last 2 years of the experiment these plots were almost 95-percent Pajón. In these last 2 years the heifers made fairly good gains on this weed, but inferior to the gains in the fertilized treatments. In view of this, Pajón will be submitted to fertilization treatments to determine its real value as a forage grass, as there is no information on this.

Although this grazing experiment continues with higher levels of nitrogen fertilization as compared to the 80 pounds of nitrogen every 4 months, the 80-pound level can be recommended as a good fertilization practice under the Lajas conditions for Guinea grass under rotational grazing.

## RESUMEN Y CONCLUSIONES

El Valle de Lajas es una región semiárida localizada en la esquina suroeste de Puerto Rico.

La lluvia anual que recibe esta región fluctúa entre 40 y 60 pulgadas y son comunes los períodos prolongados de sequía.

La yerba más importante para el pastoreo es la Guinea, pero carece de una buena atención en cuanto a su manejo y abonamiento.

En el 1952 se inició un experimento en el cual predios experimentales de esta yerba Guinea se sometieron a diferentes tratamientos de abono bajo un pastoreo rotativo.

El experimento diseñado en forma de bloques al azar, el cual se describe en otro artículo (*3*), consistió de 3 tratamientos con sulfato amónico a razón de 0, 40 y 80 libras de nitrógeno por cuerda cada 4 meses.

Los resultados de este experimento indican que el abonamiento de la yerba Guinea es lucrativo aún en regiones relativamente secas como es ésta del Valle de Lajas.

Las ganancias en peso por cuerda de los animales incluídos en este experimento fueron como sigue: 794 libras en el tratamiento de 400 libras de sulfato amónico, 530 libras en el de 200 libras y 341 libras en el tratamiento testigo sin abono. Las capacidades medias de sostenimiento fueron 1.19, 0.84 y 0.56 de cabeza de ganado adulto por acre, respectivamente, a los tratamientos mencionados. Los intervalos de pastoreo en rotación fluctuaron entre 6.5 y 10 días a través de los 4 años que duró el experimento. Las diferencias en cuanto a las ganancias en peso fueron estadísticamente significativas al nivel del 0.01 por ciento.

Los ingresos por acre sobre el costo del abono fueron los siguientes: $85 para el tratamiento de 400 libras de sulfato amónico, $63.80 para el de 200 libras, y 56.56 para el tratamiento testigo sin abono. De acuerdo con estas cifras, la aplicación de 200 libras de sulfato amónico por cuerda cada 4 meses no es suficiente para lograr un ingreso satisfactorio, ya que la diferencia entre la aplicación de este número de libras y la no aplicación de

abono alguno fué sólo de $9.34. Por otro lado, la aplicación de 400 libras del abono produjo un ingreso bruto de $34.44 sobre lo producido por el tratamiento sin abono.

Se observó que el abonamiento de la yerba Guinea induce un mayor desarrollo de las cepas, lo cual no favorece el crecimiento desmedido de los yerbajos. Sin embargo, el yerbajo conocido por Pajón *Andropogon annuatus* invadió severamente los predios experimentales sin abono hasta el extremo de que durante los últimos 2 años del experimento estos predios tuvieron hasta un 95 por ciento de Pajón. También, durante los últimos dos años se observó que las novillas lograron aumentar de peso comiendo el Pajón, pero estos aumentos fueron menores comparados con las ganancias logradas en los predios abonados. En vista de ésto, el Pajón será sometido a aplicaciones de abono para así determinar su valor real como pasto, ya que se carece de esta información.

Aunque este experimento de pastoreo continúa con niveles más altos en la aplicación de nitrógeno comparados con las 80 libras de este elemento aplicadas cada 4 meses, por ahora se puede recomendar este mismo nivel de 80 libras como una buena práctica de abonamiento en el pastoreo rotativo con yerba Guinea bajo las condiciones del Valle de Lajas.

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# Considerations on the Convenience of Distilling at High Proof in Continuous Alcoholic Distillation for Beverages

*Herminio M. Brau*[1]

## INTRODUCTION

Recently published results on studies conducted at this Rum Pilot Plant on the distribution of fusel oil along the plates of continuous distillation columns under different operating conditions, suggested the convenience of withdrawing the product from a point as high as possible along the column (*1*).[2] The data obtained indicate that, under any set of operating conditions, the higher the plate in the column, and, consequently, the higher the proof of the product, the lower would be the concentration of fusel oil in the latter. Because of the adverse effect of the oil on the quality of the finished product, the production of distillates of low fusel-oil content is most desirable in the industrial production of alcoholic beverages, especially in the case of light-type beverages such as Puerto Rican rum.

Table 1 presents selected data on fusel-oil distribution along the plates of a rectifying column containing 50 bubble-cap trays under different operating conditions (*1*). The data presented correspond to concentrations of the order of 10,000 mg. of fusel oil, expressed as amyl alcohol per 100 ml. of sample, at the plate of maximum accumulation. Large accumulations occur at several plates around the feed plate, which was plate 18 in all cases, with maximum accumulations occurring at plates 2 to 6 above the feed plate, depending on the operating conditions.

Two important considerations should be kept in mind before deciding that the most convenient practice would be that of removing the product-stream from the highest point of the column at the highest possible proof, as suggested by the results mentioned above. The dispositions of the Spirits and Alcoholic Beverages Act of Puerto Rico is the first point to be considered. This Act establishes that spirituous distillates should be produced at an alcoholic content below 190° proof in order to qualify as

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[2] Italic numbers in parentheses refers to Literature Cited, p. 257.

rum. The U. S. Spirits and Alchoholic Beverages Act establishes that, in order to be considered as whiskey, spirituous distillates should be produced at an alcoholic content below 160° proof.

The second point to be considered is the recovery of desirable congeneric substances, such as esters and acids, which are of utmost importance since

TABLE 1.—*Fusel-oil distribution in rectifying column under different operating conditions*[1]

| Plate | Feed[2]: 20-percent alcohol by volume for reflux ratio indicated | | | Feed[2]: 30-percent alcohol by volume for reflux ratio indicated | | | | Feed[2]: 40-percent alcohol by volume for reflux ratio indicated | | | Feed[2]: 50-percent alcohol by volume for reflux ratio indicated | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5:1 | 4:1 | 3:1 | 15:1 | 10:1 | 5:1 | 4:1 | 5:1 | 4:1 | 3:1 | 5:1 | 4:1 | 3:1 |
| 50 | 15 | 5 | 20 | 5 | 5 | 15 | 20 | 10 | 10 | 10 | 10 | 15 | 10 |
| 42 | 25 | 45 | 120 | 5 | 10 | 20 | 45 | 15 | 25 | 65 | 15 | 25 | 65 |
| 38 | 65 | 150 | 500 | 15 | 20 | 50 | 110 | 55 | 110 | 400 | 40 | 75 | 305 |
| 34 | 250 | 550 | 2,000 | 45 | 100 | 195 | 400 | 190 | 395 | 500 | 180 | 360 | 900 |
| 30 | 800 | 1,900 | 4,000 | 235 | 480 | 850 | 1,400 | 1,050 | 1,150 | 2,500 | 690 | 1,050 | 2,000 |
| 26 | 4,000 | 5,500 | 7,000 | 950 | 2,200 | 2,950 | 4,000 | 2,800 | 3,700 | 5,500 | 2,350 | 3,000 | 4,200 |
| 24 | 6,500 | 8,000 | 9,500 | 2,600 | 3,950 | 6,050 | 6,500 | 5,850 | 6,400 | 7,500 | 3,900 | 4,250 | 6,900 |
| 23 | 8,000 | 10,000 | 9,500 | 5,000 | 6,000 | 8,000 | 8,000 | 7,850 | 8,250 | 8,500 | 5,200 | 5,600 | 8,250 |
| 22 | 10,000 | 10,500 | 9,000 | 7,100 | 7,400 | 10,500 | 9,000 | 8,500 | 9,500 | 9,000 | 6,700 | 6,900 | 8,400 |
| 21 | 11,500 | 9,500 | 6,500 | 8,500 | 9,700 | 11,400 | 9,000 | 9,700 | 9,850 | 7,000 | 8,900 | 8,900 | 9,400 |
| 20 | 11,000 | 8,000 | 4,500 | 10,750 | 10,300 | 10,500 | 8,000 | 11,000 | 9,800 | 5,500 | 9,770 | 9,040 | 8,550 |
| 19 | 4,000 | 2,500 | 1,000 | 7,100 | 7,400 | 2,450 | 3,500 | 7,000 | 4,850 | 2,250 | 9,240 | 8,470 | 7,650 |
| 18 | 950 | 500 | 300 | 1,150 | 1,250 | 800 | 1,400 | 2,150 | 800 | 770 | 4,300 | 4,100 | 2,500 |
| 17 | 550 | 300 | 250 | 510 | 640 | 470 | 700 | 890 | 625 | 550 | 1,650 | 2,300 | 1,500 |
| 16 | 200 | 90 | 95 | 95 | 100 | 160 | 300 | 210 | 120 | 200 | 410 | 580 | 535 |
| 15 | 95 | 55 | 55 | 30 | 35 | 70 | 100 | 70 | 75 | 80 | 100 | 140 | 115 |
| 14 | 65 | 35 | 40 | 10 | 10 | 45 | 80 | 60 | 45 | 40 | 30 | 50 | 45 |
| 12 | 30 | 25 | 35 | 0 | 0 | 15 | 35 | 30 | 40 | 10 | 0 | 5 | 0 |
| 8 | 15 | 10 | 20 | 0 | 0 | 10 | 15 | 30 | 35 | 0 | 0 | 0 | 0 |
| 4 | 5 | 5 | 10 | 0 | 0 | 5 | — | 35 | 45 | 0 | 0 | 0 | 0 |

[1] Data in mg. of fusel oil as amyl alcohol per 100 ml. of sample.
[2] Feed was added at plate 18 in all cases.

it is their characteristic body, aroma and taste, developed through complex chemical reactions and physical interactions occurring during the aging process, that differentiate alcoholic beverages from industrial alcohol.

## OBJECTIVE

There are no data in the technical literature on the distribution of congeneric substances along continuous distillation columns in the process of manufacture of spirituous beverages from molasses. Theoretical considerations indicate that the concentration of volatile congeneric substances

would continuously increase toward the upper end of the column reaching a maximum concentration in the overhead distillate. There is no information regarding the possible accumulation of heavier congeneric substances at plates of lower alcoholic concentrations in the column. Several experiments were conducted in order to obtain experimental data on the distribution of congeneric substances along the plates of the rectifying column of the continuous distillation unit of this Plant.

## EXPERIMENTAL PROCEDURE

Raw distillate from the beer column of the continuous distillation unit was diluted with water to an alcoholic strength of 80° proof at 60° F. in all cases. This 80°-proof alcohol solution was fed to plate 12, from bottom up, of a 50-bubble-cap tray rectifying column without processing it in the purifying column. The rectifying column was operated at reflux ratios of 15:1, 10:1, 7:1, 5:1, and 4:1 in successive experiments. Reflux ratio is defined as the volumetric ratio between the reflux stream returned to the top of the column and the main-product side-stream. The main product was removed as a liquid side-stream from plate 42 in all cases. A heads-product stream, containing about 3 percent of the alcohol fed, was removed from the overhead distillate. A fusel-oil side-stream was removed from plate 14 in all experiments. Samples were taken from plates 50, 48, 46, 44, 42, 40, 38, and 36 at 4 and 8 hours after withdrawal of main product commenced. No samples were taken below this point since the region of very high concentration of fusel oil and other unidentified tail substances is approached. Very high concentrations of fusel oil and tail substances render the product undrinkable.

All samples were analyzed to determine their alcoholic strength as well as their contents of esters, acids, and aldehydes.

An additional experiment was conducted at a reflux ratio of 5:1 with the objective of determining whether there is any accumulation of congeneric substances, other than fusel oil, in regions of lower alcoholic content.

In this experiment samples were taken from plates 50, 46, 42, 40, 38, 36, 34, 32, 30, 28, 26, 24, 22, 20, 18, 16, 14, 10, 6, and 2 at 8 hours after withdrawal of main product commenced. All samples were analyzed to determine their alcoholic strength as well as their contents of esters, acids, and aldehydes.

## EQUIPMENT UTILIZED

The experimental work reported in this paper was conducted utilizing the rectifying column of the continuous distillation unit of the Rum Pilot Plant of this Station. This column contains 50 bubble-cap plates, 15″ nominal diameter at 12″ plate-spacing. The column is provided with a total condenser and a reflux collector from which the reflux and the heads-

product streams are removed. The reboiler of the column is an outside shell and tube evaporator utilizing indirect steam. A steam heater is installed in the feed line to maintain a constant temperature in the feed. All plates of the column are provided with sampling facilities. In addition, the column is provided with numerous automatic and manual control instruments as described below.

## CONTROL SYSTEM UTILIZED

The control system utilized includes automatic temperature controllers to regulate the temperature of the feed and reflux streams at any desired value. The boil-up rate of the column is controlled by an automatic differential-pressure controller which, in turn, resets an automatic steam flow-rate controller to the reboiler. The differential-pressure instrument is tapped near the bottom and top ends of the column. The rate of flow of the reflux, heads, and main-product streams are automatically controlled in all cases. The flow of the bottom product is regulated by an automatic level controller which maintains enough liquid in the column to cover the tubes of the reboiler. The control system utilized in the course of these studies for the operation of the rectifying column was that developed at this Plant; it consists of varying the rate of feed to the column in order to maintain constant a reference temperature in the plate just above the feed plate (*2*). By selecting the appropriate reference-temperature value, the liquid flowing from the plate just above the feed plate, which mixes with the feed in the downtake, has approximately the same composition as the feed itself. By maintaining constant all the variables which affect the distribution of compositions at the enriching section of the column, it is possible to obtain very stable compositions in said enriching section from which the main-product and byproduct streams are removed.

## RESULTS

The results of these studies are presented on tables 2 to 7. The data of tables 2 to 6, on the distribution of congenerics in the upper region of the column, definitely indicate that the concentration of congenerics in the plates of the column increases, the higher the plate, reaching a maximum in the overhead distillate. There is no indication of any accumulation of congeneric substances in intermediate plates of this region of high alcoholic strengths. The absolute concentration of each particular congeneric at the various plates of the column will depend on the composition of the feed as well as on the operating conditions utilized. The data obtained indicate, however, that, irrespective of the magnitude of the concentration of the various congenerics, there will always be a greater concentration of these substances the higher the plate in the column.

The results in table 7, which correspond to the experiment conducted

with the objective of exploring other regions of the column, also indicate that there is no significant accumulation of congeneric substances at

TABLE 2.—*Distribution of congenerics in rectifying column for these experimental conditions: Feed—40-percent alcohol at plate 12; reflux ratio—15:1; product—plate 42*[1]

| Plate | 4-hour samples | | | | 8-hour samples | | | |
|---|---|---|---|---|---|---|---|---|
| | Alcohol | Aldehydes | Acids | Esters | Alcohol | Aldehydes | Acids | Esters |
| Heads | 192.7 | 150.7 | 2.2 | 26.7 | 193.2 | 105.5 | 4.1 | 20.4 |
| 50 | 193.6 | 85.9 | 2.2 | 21.0 | 193.4 | 66.5 | 1.0 | 10.1 |
| 48 | 193.6 | 49.2 | 1.6 | 7.9 | 193.1 | 44.8 | .7 | 3.2 |
| 46 | 193.4 | 33.5 | .5 | 2.7 | 193.1 | 26.3 | .5 | 1.6 |
| 44 | 193.2 | 22.5 | .4 | 2.7 | 192.9 | 19.6 | .4 | 0 |
| 42 | 192.9 | 15.3 | .4 | 1.7 | 192.7 | 14.2 | .4 | 0 |
| 40 | 192.5 | 12.1 | .2 | 2.5 | 192.5 | 10.6 | .4 | 0 |
| 38 | 192.3 | 10.6 | .2 | .8 | 192.3 | 7.4 | .4 | 0 |
| 36 | 192.2 | 7.8 | .2 | .5 | 191.8 | 5.9 | .2 | 0 |

[1] The alcohol is expressed in degrees proof at 60°F.; the concentration of aldehydes, acids, and esters is expressed, respectively, as milligrams of acetaldehyde, acetic acid, and ethyl acetate per 100 ml. of sample.

TABLE 3.—*Distribution of congenerics in rectifying column for these experimental conditions: Feed—40-percent alcohol at plate 12; reflux ratio—10:1; product—plate 42*[1]

| Plate | 4-hour samples | | | | 8-hour samples | | | |
|---|---|---|---|---|---|---|---|---|
| | Alcohol | Aldehydes | Acids | Esters | Alcohol | Aldehydes | Acids | Esters |
| Heads | 192.1 | 176.0 | 2.3 | 38.3 | 193.2 | 198.7 | 2.9 | 42.7 |
| 50 | 193.2 | 98.6 | .8 | 18.7 | 193.4 | 110.4 | .6 | 22.4 |
| 48 | 193.1 | 55.9 | .5 | 6.1 | 193.2 | 62.0 | .6 | 10.3 |
| 46 | 193.0 | 38.1 | .5 | .2 | 193.1 | 36.2 | .4 | .8 |
| 44 | 192.8 | 22.1 | .4 | .2 | 192.9 | 21.7 | .4 | 0 |
| 42 | 192.6 | 14.9 | .4 | .3 | 192.6 | 16.0 | .4 | 0 |
| 40 | 192.1 | 10.8 | .4 | .4 | 192.3 | 10.9 | .4 | 0 |
| 38 | 192.0 | 8.8 | .2 | .3 | 192.0 | 8.2 | .4 | 0 |
| 36 | 191.5 | 6.6 | .2 | .2 | 191.2 | 5.9 | .4 | 0 |

[1] The alcohol is expressed in degrees proof at 60°F.; the concentration of aldehydes, acids, and esters is expressed, respectively, as milligrams of acetaldehyde, acetic acid, and ethyl acetate per 100 ml. of sample.

intermediate plates of columns, with the exception of the esters. In this latter case the data of table 7 show that there is some accumulation of esters at plates of high fusel-oil accumulation, *i.e.*, several plates around

the feed plate, which was plate 12 in this experiment. The data of table 1 indicate that this is precisely the region of maximum fusel-oil accumulation.

TABLE 4.—*Distribution of congenerics in rectifying column for these experimental conditions: Feed—40-percent alcohol at plate 12; reflux ratio—7:1; product—plate 42*[1]

| Plates | 4-hour samples | | | | 8-hour samples | | | |
|---|---|---|---|---|---|---|---|---|
| | Alcohol | Aldehydes | Acids | Esters | Alcohol | Aldehydes | Acids | Esters |
| Heads | 192.0 | 232.9 | 2.0 | 52.0 | 192.9 | 199.7 | 3.2 | 43.6 |
| 50 | 193.0 | 137.4 | 1.2 | 27.3 | 193.2 | 110.9 | .7 | 25.0 |
| 48 | 192.9 | 81.3 | .8 | 4.4 | 193.0 | 67.3 | .6 | 13.7 |
| 46 | 192.8 | 50.2 | .5 | .7 | 192.6 | 38.2 | .5 | .6 |
| 44 | 192.6 | 31.4 | .4 | .8 | 192.2 | 24.0 | .5 | .2 |
| 42 | 192.0 | 18.5 | .2 | .8 | 192.0 | 15.3 | .5 | 0 |
| 40 | 191.4 | 11.2 | .2 | .2 | 191.5 | 11.0 | .5 | 0 |
| 38 | 191.1 | 7.6 | .2 | .2 | 190.9 | 8.5 | .4 | 0 |
| 36 | 190.4 | 6.8 | .2 | .3 | 190.5 | 7.3 | .4 | 0 |

[1] The alcohol is expressed in degrees proof at 60°F.; the concentration of aldehydes, acids and esters is expressed, respectively, as milligrams of acetaldehyde, acetic acid, and ethyl acetate per 100 ml. of sample.

TABLE 5.—*Distribution of congenerics in rectifying column for these experimental conditions: Feed—40-percent alcohol at plate 12; reflux ratio—5:1; product—plate 42*[1]

| Plate | 4-hour samples | | | | 8-hour samples | | | |
|---|---|---|---|---|---|---|---|---|
| | Alcohol | Aldehydes | Acids | Esters | Alcohol | Aldehydes | Acids | Esters |
| Heads | 191.4 | 207.9 | 1.1 | 42.2 | 191.9 | 309.1 | 1.6 | 70.2 |
| 50 | 193.0 | 112.9 | .8 | 24.0 | 192.8 | 162.5 | 1.2 | 41.9 |
| 48 | 192.7 | 60.6 | .6 | 12.2 | 192.6 | 91.4 | .7 | 22.8 |
| 46 | 192.3 | 35.1 | .5 | 6.8 | 192.3 | 50.6 | .7 | 7.5 |
| 44 | 191.9 | 20.8 | .5 | 1.7 | 191.9 | 27.8 | .5 | 4.0 |
| 42 | 191.5 | 13.6 | .5 | 1.4 | 191.3 | 18.3 | .5 | .6 |
| 40 | 190.5 | 8.8 | .5 | 1.4 | 190.6 | 11.0 | .5 | .2 |
| 38 | 189.7 | 6.4 | .5 | .6 | 189.5 | 8.4 | .5 | 0 |
| 36 | 189.2 | 5.8 | .5 | — | 189.0 | 6.0 | .5 | 0 |

[1] The alcohol is expressed in degrees proof at 60°F.; the concentration of aldehydes, acids, and esters is expressed, respectively, as milligrams of acetaldehyde, acetic acid, and ethyl acetate per 100 ml. of sample.

It should be kept in mind that plate 18 was the feed plate on the experiments reported in table 1.

The nauseating taste and odor of the liquid accumulating in this region

TABLE 6.—*Distribution of congenerics in rectifying column for these experimental conditions: Feed—40-percent alcohol at plate 12; reflux ratio—4:1; product—plate 42*[1]

| Plate | 4-hour samples | | | | 8-hour Sample | | | |
|---|---|---|---|---|---|---|---|---|
| | Alcohol | Aldehydes | Acids | Esters | Alcohol | Aldehydes | Acids | Esters |
| Heads | 191.4 | 225.0 | 2.2 | 56.8 | 192.7 | 227.9 | 3.5 | 79.8 |
| 50 | 192.3 | 120.6 | 1.4 | 33.3 | 192.7 | 124.4 | 2.3 | 50.0 |
| 48 | 192.2 | 69.0 | 1.0 | 16.6 | 192.2 | 73.9 | 1.4 | 24.6 |
| 46 | 191.8 | 40.2 | .6 | 5.3 | 191.8 | 43.7 | .7 | 4.8 |
| 44 | 191.0 | 23.6 | .4 | 4.8 | 191.4 | 24.2 | .5 | .5 |
| 42 | 190.3 | 14.0 | .4 | 2.6 | 190.6 | 16.2 | .5 | 0 |
| 40 | 189.4 | 10.3 | .2 | 2.0 | 190.0 | 10.6 | .5 | 0 |
| 38 | 188.3 | 7.8 | .2 | 1.6 | 189.1 | 8.6 | .4 | 0 |
| 36 | 187.2 | 5.0 | .2 | 1.2 | 188.3 | 6.9 | .4 | 0 |

[1] The alcohol is expressed in degrees proof at 60°F.; the concentration of aldehydes, acids, and esters is expressed, respectively, as milligrams of acetaldehyde, acetic acid, and ethyl acetate per 100 ml. of sample.

TABLE 7.—*Distribution of congenerics in rectifying column for these experimental conditions: Feed—40-percent alcohol at plate 12; reflux ratio—5:1; product—plate 42*[1]

| Plate | Congenerics content of 8-hour sample | | | |
|---|---|---|---|---|
| | Alcohol | Aldehydes | Acids | Esters |
| Heads | 192.9 | 270 | 2.3 | 105.2 |
| 50 | 192.9 | 146.3 | .2 | 62.7 |
| 46 | 192.4 | 60.9 | .2 | 12.4 |
| 42 | 191.4 | 29.6 | 0 | 2.7 |
| 40 | 191.0 | 20.0 | 0 | 2.6 |
| 38 | 190.5 | 14.8 | 0 | 2.8 |
| 36 | 189.6 | 10.4 | 0 | 2.0 |
| 34 | — | 8.2 | 0 | 2.8 |
| 32 | 188.7 | 6.7 | .1 | 2.1 |
| 30 | 188.3 | 5.9 | 0 | 6.7 |
| 28 | 186.0 | 6.1 | 0 | 6.8 |
| 26 | 184.8 | 5.4 | 0 | 4.7 |
| 24 | 183.1 | 4.6 | 0 | 7.6 |
| 22 | 180.0 | 4.3 | 0 | 9.9 |
| 20 | 178.6 | 2.5 | 0 | 8.8 |
| 18 | 174.4 | 4.3 | 0 | 14.4 |
| 16 | 166.9 | 4.2 | 0 | 22.4 |
| 14 | 154.3 | 3.9 | .1 | 41.2 |
| 10 | 71.7 | 1.7 | .1 | 25.1 |
| 6 | .8 | 1.5 | 0 | 4.4 |
| 2 | 0 | 1.8 | 0 | .3 |

[1] The alcohol is expressed in degrees proof at 60°F.; the concentration of aldehydes, acids, and esters is expressed, respectively, as milligrams of acetaldehyde, acetic acid, and ethyl acetate per 100 ml. of sample.

of the column make it unsuitable for use in beverages. Undoubtedly, the esters accumulating in this region of the column are, like fusel oil, less volatile than ethyl alcohol and at the same time virtually insoluble in water. Being less volatile than the alcohol these esters and the fusel oil are forced down from the upper trays by rectification. As they pass down to the bottom of the column they become immisible in the higher water concentrations and steam distillation forces them to rise. Being unable to escape by either end of the column, because of the two opposing effects, these esters and the fusel oil accumulate at same intermediate plates of the column.

It is recognized that, very possibly because of their particular nature, the presence of these esters in the distillate, free from the fusel oil which accumulates with them, would contribute notably to the quality and character of the final product. The presence of high concentrations of the accompaning fusel oil and tail substances, however, will more than offset any benefitial effect. The development of techniques which would allow the recovery of these heavier esters while eliminating the fusel oil and tail substances which accumulate in the same fraction, will be the subject of studies to be conducted in the near future in this Plant.

It can be seen from data presented that, in many instances, the heads product has a somewhat lower alcoholic content than the liquid from the top plate of the column, *i.e.*, plate 50. This is attributed to evaporation losses which occurred while collecting the heads-product stream in an open receiving tank.

## CONCLUSIONS

The results presented in this paper, as well as those presented in a previous publication on the distribution of fusel oil along continuous distillation columns under different operating conditions, indicate that, by removing the main-product stream from a higher point in the column, a lower fusel-oil content is obtained in the main product without sacrificing the recovery of congeneric substances. On the contrary, it can be said that a greater recovery of congenerics could be achieved by removing the product from higher plates at higher proof. Of course, the quantity of congenerics recovered can be controlled by varying the operating conditions such as the size of the heads-stream and the plate from which the main-product stream would be withdrawn. By adequatelly adjusting these operational variables the main product could be varied from a very light alcohol to a rather heavier one containing most of the congenerics present in the raw distillate. Obviously, the latter would be an extreme condition of doubtful convenience because of the very high content of aldehydes that would be obtained in the main product. The data obtained indicate that only in the case of the esters is there some accumulation of these substances

in the region of high accumulation of fusel oil. The marked adverse effect produced by the extremely high concentration of fusel oil and tail substances found in this region of the column, would more than offset any goodness in the quality of the final product produced by the recovery of these esters.

Utilizing the conventional Barbet continuous-distillation system and operating in such a fashion as to obtain a product of 180° to 189° proof, or even less, it is possible to obtain a product of very low concentration of esters, aldehydes, and acids. In any particular case, other conditions, such as the composition of the feed, the number of trays in the column, the feed plate, and the reflux ratio, remaining the same, the product would be lighter in its fusel oil and tail substances content by distilling at a higher proof and withdrawing the product from a higher plate in the column.

Thus, the proof of the distillate would limit the elimination of fusel oil and tail substances which definitely detract from the quality of the product and which are considered by many as more harmful to the health of the public than other congeneric substances, and mostly responsible for "hangover" and other objectionable aftereffects.

During the course of our studies on various phases of the alcoholic distillation from fermented cane molasses it has been found repeatedly that liquids from the bottom and from several trays above the reboiler of continuous distillation columns, which are free from fusel oil and other congeneric substances, still possess the characteristic "tail" odor frequently attributed to fusel oil and which is evidently caused by unidentified substances not accounted for by the classical chemical analysis for esters, acids, aldehydes, and higher alcohols.

In other words, by producing main-product distillates at very high alcoholic content, say 192° proof, and by properly selecting other operational variables, it is more easily possible to obtain a product containing similar concentrations of esters, acids, and aldehydes than by distilling below 190°— or below 160° proof—but with the distinct advantage that the 192°-proof distillate would be lower in its content of fusel oil and tail substances.

Further, with the utilization of extractive distillation technics the use of the proof of the distillate as a criterion for determining whether it is a beverage or a neutral spirit becomes obsolete. By the utilization of extractive-distillation methods it is possible to eliminate virtually all congeneric substances in the extractive distillation column. The dilute product from the extractive-distillation column is fed subsequently into a rectifying column and a distillate at a relatively low alcoholic content can be produced which still would be a neutral spirit due to the virtual absence of congeneric substances. Thus, the elimination of congenerics can be achieved even more completely by the utilization of modern extractive methods. Ac-

cordingly, it is the opinion of this author that there is no justification for the restriction of the Law regarding the alcoholic content of distillates from molasses, and possibly from other substrates, as a basis for classification as a spirituous beverage or as a neutral spirit.

## SUMMARY

The results of these studies on the distribution of congenerics along continuous distillation columns, as well as previously published results on the distribution of fusel oil under different operating conditions, indicate the convenience of distilling at the highest possible proof within the limits established by the Law. By distilling at higher proof, and by properly selecting other operational variables, it is possible to recover congeneric substances to any desired extent while reducing the content of fusel oil and unidentified tail substances in the main product. It is recognized that the presence of the latter detracts from the quality of alcoholic beverages.

## RESUMEN

Los resultados de estos estudios sobre la distribución de congenéricos a lo largo de las columnas de destilación, así como resultados publicados anteriormente sobre la distribución de concentraciones de aceite de fúsel bajo diferentes condiciones de operación, señalan la conveniencia de destilar al grado prueba más alto que sea posible dentro de los límites fijados por la Ley. Destilando a alta prueba y seleccionando adecuadamente las demás variables de operación, es posible recuperar con el producto principal substancias congenéricas en la medida que se desee, mientras se reduce el contenido de aceite de fúsel y de otras substancias no identificadas y que son responsables del olor y sabor a colas en la destilación alcohólica.

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# Control of the Red-Banded Thrips, *Selenothrips rubrocinctus* Giard, on *Acalypha*

*Silverio Medina Gaud*[1]

## INTRODUCTION

The red-banded thrips, *Selenothrips rubrocinctus* Giard (*1*)[2], is one of the most common and injurious species of thrips attacking a large variety of plants, shrubs, and trees in our Island. Lately these insects have been observed doing severe damage to the foliage of such ornamental plants as *Acalypha wilkesiana* Muell. Arg. and *A. wilkesiana* variety *marginata*. The observations have been made at the Río Piedras Agricultural Experiment Station (P. R. Acc. No. 62-57)[3] and the Corozal Substation (P. R. Acc. No. 67-57). At the Río Piedras Station they have been also observed on the foliage of guava, *Psidium guajava* L. (P. R. Acc. No. 50-56) and as a new host record on the West Indian mahogany, *Swietenia mahagoni* Jacq. (P. R. Acc. No. 7-55), on cacao, *Theobroma cacao* (P. R. Acc. No. 68-57), "María", *Callophyllum antillanum* Britton (P. R. Acc. No. 69-57), "reina de las flores", *Lagerstroemia speciosa* Kochne (P. R. Acc. No. 75-57) and "croton", *Codiaeum variegatum* (L.) Blume (P. R. Acc. No. 78-57).

## THE INSECT AND ITS CONTROL

### DESCRIPTION

These minute inconspicuous insects belong to the group of the socalled thrips, of the order Thysanoptera. The common name of this insect is "cacao thrips", because of its ravages on the cacao plantations in some of the West Indian Islands (*5*), but they are also known as red-banded thrips from the color of the nymphs. The adult thrips is a small black insect having an average length of $\frac{1}{24}$ of an inch. It is characterized by a body of deeply reticulated structure, particularly as to the head and prothorax, the head broader than long, with a very irregular and rough outline. Antenna eight-segmented; legs unarmed; wings, four in number, present. It derives its common and specific name from the nymphs, which are smaller than the adult, but yellowish in color with a distinct red band on the abdomen (fig. 1).

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[2] Italic numbers in parentheses refer to Literature Cited, p. 266.

[3] Reference to accession numbers in Card Catalog of the insect collection at the Agricultural Experiment Station.

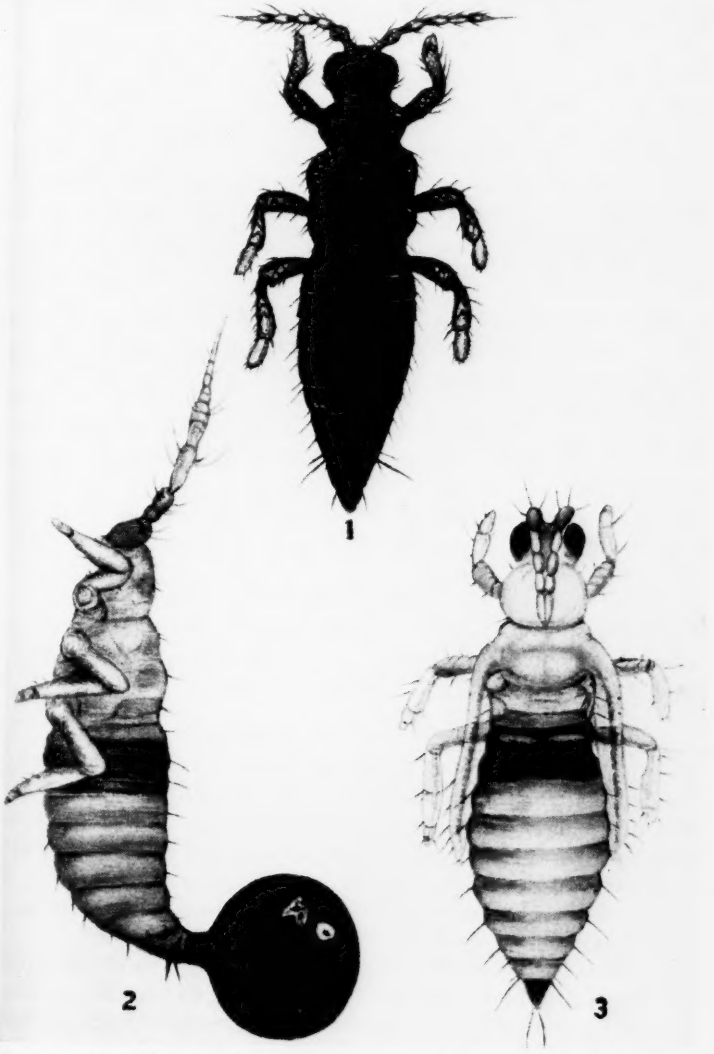


FIG. 1.—*Selenothrips rubrocinctus* (Giard): 1, Adult female at rest. 2, Full-grown larva in characteristic attitude as seen on cacao pods and leaves, with drop of liquid excrement on tip of abdomen. 3, Pupa. All magnified about 50 diameters. From: F. W. Urich, "The Cacao Thrips", Board of Agriculture of Trinidad, Feb. 1911.

### TYPE OF INJURY

Both the nymphs and adults rasp the surface of the parts of the plants attacked and feed on the juices thus liberated. As a result of this type of feeding they cause a severe chlorosis on the leaves, sometimes giving a silvery appearance to the foliage. The surface cells die, after first turning silvery and later brown. The young nymphs also excrete from the tip of the abdomen a ball of brown semiliquid material which they carry about and later deposit on the leaves. This substance gives the leaves a dirty, flyspecked appearance.

### HOSTS

In Puerto Rico this insect has been recorded from mango, *Mangifera indica* L.; tropical almond, *Terminalia cattapa* L.; avocado, *Persea americana* Mill.; guava, *Psidium guajava* L.; cashew, *Anacardium occidentale* L.; "jobo", *Spondias mombin* L.; "icaco", *Chrysobalanus icacao* L.; "achiote", *Bixa orellana* L.; "espino rubial", *Zanthoxylum monophyllum* Lam.; "uvilla" or "cucubano", *Coccolobis laurifolia* Jacq.; muscadine grape, *Vitis rotundifolia* Michx.; mangosteen, *Garcinia mangostana* L.; "cenizo", *Zanthoxylum martinicense* (Lam.) D. C.,; Himalaya raspberry, Cuthbert raspberry, and Burbank thornless berry (*1*, *2*, *3*, *7*, *8*).

### DISTRIBUTION

The red-banded thrips has been recorded from Grenada, St. Vincent, St. Lucia, Dominica, Guadeloupe, Trinidad, Tobago, Virgin Islands, Uganda, East Africa, Island of Mauritius, Ceylon, and Florida, U.S. (*4*, *6*).

### EXPERIMENTAL MATERIAL AND METHODS OF CONTROL

A control experiment was carried on April 2, 1957. The insecticides used in this test were 34-percent Pennsalt DDT emulsion concentrate containing 3 pounds of DDT per gallon, Pennsalt BHC emulsion E-11 containing 1 pound of gamma isomer per gallon, 25-percent Pennsalt Aldrin (Compound 118) containing 2 pounds of technical Aldrin per gallon, and 19.5-percent Shell Endrin emulsifiable concentrate containing 1.6 pounds of Endrin per gallon.

The experiment was conducted on a 76-foot *Acalypha wilkesiana* hedge, 3 to 4 feet high, with an average width of 2 feet. The hedge was divided into 10 plots, each plot with 5 plants, with an approximate length of 6 feet, leaving 3 buffer plants between treatments. The treatments were replicated twice. The insecticides were applied with a 4½-gallon knapsack sprayer using 2 gallons of spray for each treatment.

Results of the treatments were determined by counting the number of

live thrips before and after the spraying on samples of 50 leaves per plot taken at random from top, bottom, and sides. A total control was obtained within 48 hours (table 1). The status of the thrips population was determined again 15 days after the first examination on April 17, 1957. The plots sprayed with Aldrin showed no reinfestation; all other plots treated showed slight reinfestation from adjoining untreated plants heavily infested with thrips.

## RECOMMENDATION FOR CONTROL

The insecticides used were effective in controlling the red-banded thrips on *Acalypha*. The insecticides should be used as follows: Concentrated

TABLE 1.—*Results of using specified insecticides for the control of red-banded thrips,* Selenothrips rubrocinctus *Giard*

| Insecticides and dilution | Number of live thrips on 50 leaves per plot— | | | | | |
|---|---|---|---|---|---|---|
| | Before treatment, Apr. 2, 1957 | | After treatment | | | |
| | | | Apr. 4, 1952 | | Apr. 17, 1957 | |
| | Adults | Nymphs | Adults | Nymphs | Adults | Nymphs |
| BHC: 1 pint/100 gal. water | 335 | 270 | 0 | 0 | 3 | 10 |
| Endrin: 1 pint/100 gal. water | 258 | 229 | 0 | 0 | 3 | 0 |
| DDT: 1 pint/100 gal. water | 301 | 170 | 0 | 0 | 7 | 29 |
| Aldrin: 1 pint/100 gal. water | 307 | 183 | 0 | 0 | 0 | 0 |
| Buffer—between treatment rows—nontreated | 228 | 179 | 134 | 220 | 117 | 1,655 |
| Check, nontreated | 328 | 271 | 196 | 279 | 135 | 1,235 |

emulsion of either BHC, Endrin, DDT, or Aldrin, at the rate of 1 pint of the emulsion in 100 gallons of water. Spray at intervals of 2 weeks, giving two or three applications.

## SUMMARY

The red-banded thrips, *Selenothrips rubrocinctus* Giard, is one of the most common and injurious species of insects attacking a large variety of plants, shrubs, and trees in our Island. This insect has been recorded from the Lesser Antilles, Virgin Islands, East Africa, and Florida. A series of host plants are recorded and the insect is described. Some insecticides were tested, mainly BHC, Endrin, DDT, and Aldrin. Each of them, when used at the rate of 1 pint of the concentrate emulsion in 100 gallons of water, is effective for the control of the pest. The spray should

be applied at intervals of 2 weeks. From two to three applications effect complete control.


## RESUMEN

El trípido de las bandas rojas, *Selenothrips rubrocinctus* Giard es uno de los insectos más comunes y perjudiciales. Ataca a una gran variedad de plantas, arbustos y árboles en la Isla. La especie también ha sido encontrada en las Antillas Menores, las Islas Vírgenes, Africa Oriental y Florida. Se describe el insecto y se incluyen las plantas hospedadoras del mismo. Se probaron algunos insecticidas, entre ellos, BHC, Endrín, DDT y Aldrín. Cualquiera de éstos, usado a razón de una pinta de la emulsión concentrada en 100 galones de agua, es eficaz para su control. Las aspersiones deben hacerse a intervalos de 2 semanas. Dos o tres aplicaciones son suficientes para obtener un completo control.


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# *Myzus persicae* (Sulzer) in Puerto Rico

*Clyde F. Smith*[1], *L. F. Martorell*[2], *and M. E. Pérez-Escolar*[3]

## INTRODUCTION

The green peach aphid, *Myzus persicae* (Sulzer) has been recorded as a pest of tobacco in Puerto Rico since 1950–51, Wolcott (*5*)[4]; however, it has been reported since 1916, Wolcott (*3*), on the following host plants: Eggplant, pepper, potato, tomato, sweetpotato, and sesame. Lately, it has been observed by Adsuar, Wolcott, and Martorell on ground cherry, *Physalis angulata* L., wire-weed, *Sida carpinifolia* L. f., and papaya, *Carica papaya* L.

In 1954 and again in 1955, the senior author was invited to Puerto Rico to make a survey of the distribution and host plants of the peach aphid. The survey was made during the season when tobacco was not being grown, July and August 1954, and just as the crop was being harvested, February and March 1955. Martorell and Pérez made additional observations and collections during the interim.

## RESULTS OF SURVEY

During the "off-season", July and August, *Myzus persicae* was commonly found on peppers which were being grown in home gardens and commercial gardens. This is significant because peppers are known to harbor one important disease of tobacco in Puerto Rico, namely the pepper-mosaic virus. Thus the pepper plants may serve as a reservoir for the disease and also for the aphids. This disease has been studied previously by Roque and Adsuar (*2*) and lately by Pérez, Adsuar, and Padilla (*1*). The virus causing the mosaic disease of peppers in Puerto Rico is transmitted from pepper to tobacco and vice versa by the common green peach aphid. This virus is also transmitted mechanically. Another common virus of tobacco in Puerto Rico is transmitted to peppers and from peppers again to tobacco by mechanical means and not by any type of insect vector. A full account of these pepper and tobacco diseases is given in the publications mentioned above.

Several other plants also serve as alternate hosts (see host list, table 1) and all of them could play an important role as a source of infestation for

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[4] Italic letters in parentheses refer to Literature Cited, p. 266.

new tobacco. However, observations by Pérez indicate that sweetpotatoes may be one of the most important sources of infestation for tobacco because the sweetpotato is very common in Puerto Rico, being grown in rotation with tobacco or in the vicinity of tobacco, and it usually has a very heavy infestation of *Myzus persicae* just at the time tobacco is being set into the field. Young sweetpotato shoots are also commonly infested with aphids and are quite common in fields that have been harvested, thus creating

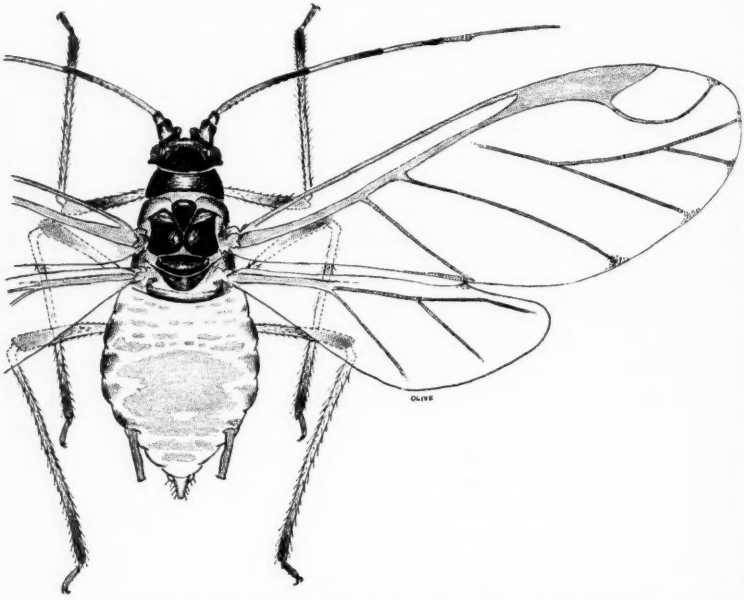


FIG. 1.—Winged alate of *Myzus persicae* (Sulzer). Drawing by Tom Olive, North Carolina State College, Department of Entomology.

an ideal source of infestation. In general the infestation does not occur in the plant bed as is often common in the United States but usually occurs after the plants are set in the field.

*Myzus persicae* (fig. 1) is common and often occurs in damaging numbers on tobacco in all areas of Puerto Rico where tobacco is grown. Table 1 is a list of the other hosts upon which *M. persicae* has been collected at various locations in Puerto Rico, and one in Haiti.

## SUMMARY

The green peach aphid, *Myzus persicae* Sulzer, is a pest of tobacco in Puerto Rico. This insect is also a vector of virus diseases transmitted from

TABLE 1.—*Host list for* Myzus persicae

| Host | Location | Date |
|---|---|---|
| *Apium graveolens* | Cayey | Mar. 8, 1955 |
| *Borreria verticillata* | Guajataca Gorge, Quebradillas | Mar. 1, 1955 |
| *Brassica integrifolia* | Cayey | Oct. 26, 1954 |
| | | Nov. 16, 1954 |
| | | Nov. 22, 1954 |
| | | Mar. 8, 1955 |
| | Cayey-Cidra Road | Sept. 19, 1954 |
| | | Sept. 22, 1954 |
| | | Sept. 28, 1954 |
| | Río Piedras | Mar. 7, 1954 |
| *B. oleracea* | Cayey | Mar. 8, 1955 |
| *Capsicum* sp. | Río Piedras | Aug. 1, 1954 |
| | | Aug. 2, 1954 |
| | Cayey-Cidra Road | Sept. 22, 1954 |
| | Rammey Field, Aguadilla | July 21, 1954 |
| *C. annuum* | Cayey | Mar. 8, 1955 |
| | Río Piedras | Mar. 7, 1955 |
| *Chenopodium ambrosioides* | Barrio Rincón, Cidra | Feb. 28, 1955 |
| *Cleome gynandra* | Cayey | Oct. 19, 1954 |
| | Isabela | Apr. 1, 1955 |
| *Clerodendron fragans* | Cayey | Mar. 8, 1955 |
| *Emilia coccinea* | Cayey-Salinas Road | Mar. 16, 1955 |
| | Cayey-Caguas Road | Mar. 16, 1955 |
| *E. sonchifolia* | Cidra | Sept. 28, 1954 |
| | | Oct. 5, 1954 |
| *Fleurya aestuans* | Cayey | Mar. 8, 1955 |
| *Ipomoea batatas* | Treasure Island, Cidra | Feb. 28, 1955 |
| | Cayey-Caguas Road | Mar. 16, 1955 |
| | Cidra | Oct. 5, 1954 |
| | | Oct. 10, 1954 |
| *Lactuca floridana* | Ciales-Jayuya Road | Mar. 2, 1955 |
| *L. sativa* | Rammey Field, Aguadilla | July 21, 1954 |
| *Moringa oleifera* | Sabana Grande-Yauco Road | Mar. 11, 1955 |
| *Nicotiana tabacum* | Cayey-Caguas Road | Mar. 16, 1955 |
| | Río Piedras-Caguas Road | Feb. 28, 1955 |
| | Cidra | Nov. 9, 1954 |
| | Sabana Grande-Yauco Road | Mar. 11, 1955 |
| | Cidra | Dec. 17, 1954 |
| | Río Piedras | Nov. 6, 1954 |
| | Cayey-Salinas Road | Dec. 17, 1954 |
| | Isabela | Dec. 28, 1954 |
| | Cayey | Mar. 18, 1955 |
| *Physalis pubescens* | El Collao-Cayey Road | Mar. 11, 1955 |
| *P. turbinata* | Cayey-Caguas Road | Mar. 16, 1955 |
| *Polianthes tuberosa* | Río Piedras | Mar. 4, 1955 |
| *Polyscias quilfoylei* | Río Grande | Mar. 9, 1955 |
| *Senecio confusus* | Ciales-Jayuya Road | Mar. 2, 1955 |
| *Solanum melongena* | Río Piedras | Mar. 7, 1955 |
| *S. nigrum* | Cayey-Caguas Road | Mar. 16, 1955 |
| *Spondias purpurea* | Cayey-Salinas Road | Feb. 28, 1955 |
| *Tectona grandis* | Cayey | Mar. 8, 1955 |
| *B integrifolia* | Chalet de Felurs, Haiti | Feb. 25, 1955 |
| | Cayey | Oct. 19, 1954 |
| | | Dec. 17, 1954 |
| Unidentified cruciferous plant | Lajas Substation | Aug. 12, 1954 |

pepper to tobacco and vice-versa. During a survey made in Puerto Rico by the authors, the known host-plant list of this insect was greatly increased by adding around 15 new records.


## RESUMEN

El pulgón verde, *Myzus persicae* Sulzer, es una plaga del tabaco en Puerto Rico. Este insecto es también el vector de enfermedades virosas trasmitidas del pimiento al tabaco y viceversa. Durante un catastro efectuado en la Isla por los autores, la lista ya conocida de plantas hospedadoras de esta especie se aumentó al añadirle alrededor de 15 nuevos récords.


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# *RESEARCH NOTE*

## *NOTES ON THE ECOLOGY OF COFFEE PLANTATIONS*

An investigation of the ecology of coffee plantations reveals certain aspects of outstanding interest. There are a number of coffee plantations in the mountainous areas of Puerto Rico which, despite the replacement by coffee trees of the arboreal species of the original forest, remain, as formerly, a favorable habitat for most of the native fauna of invertebrate animals. It is clearly evident as result of collections, notes, and data gathered during trips made at various times in the mountains of the Antilles, that coffee plantations are ecological complexes of great value.

It is clear that the principal group of trees removed in favor of coffee trees are the flora of tree ferns. As an example of the change in the composition of species let us consider the flora of Puerto Rican coffee plantations, and then follow this with a list of certain invertebrates belonging to two phyla. Within coffee plantations of this type we find, in addition to coffee trees, an admixture of orange trees, bananas, mangoes, species of *Ficus*, *Inga*, and *Cecropia*, all species of trees designed to provide the shade required by a coffee tree. There are also occasional remnants of tree ferns.

We present herewith lists of land mollusks and spiders of the web families, thus contrasting a ground-dwelling fauna with a fauna that has great powers of aerial dispersion. It should be noted that a comparison between a list of the snails of a coffee plantation and one from the original forest demonstrates a difference of less degree that we might expect, a phenomenon that can be explained by a natural flora of shrubs and ground plants. As far as the web spiders go, practically all species which normally occupy seasonal habitats in trees and shrubs are present. The following land snails are to be found:

1. *Alcadia striata* (Lamarck)
2. *Farcimen croceum* (Gmelin)
3. *Succinea approximans* Shuttleworth
4. *Zonitoides arboreus* (Say)
5. *Guppya gundlachi* (Pfeiffer)
6. *Austroselenites alticola* H. B. Baker
7. *Obeliscus terebraster* (Lamarck)
8. *Subulina octona* (Bruguiere)
9. *Bulimulus exilis* (Gmelin)
10. *Lacteoluna selenina* (Gould)
11. *Platysuccinea portoricensis* (Shuttleworth)
12. *Polydontes lima* (Ferussac)
13. *Caracolus carocolla* (Linnaeus)

The following web spiders are also in evidence:

1. *Modisimus caeruleolineatus* Petrunkevitch
2. *Achaearanea portoricensis* (Petrunkevitch)
3. *Theridion delebile* Petrunkevitch
4. *Sphyrotinus guanicae* (Petrunkevitch)
5. *Theridula gonygaster* Simon
6. *Conopistha cambridgei* (Keyserling)
7. *Capichameta jayuyensis* (Petrunkevitch)
8. *Plesiometa argyra* (Walckenaer)
9. *Leucauge regnyi* (Simon)
10. *Argyope argentata* (Fabricius)
11. *Wendilgarda theridionina* Simon
12. *Gasteracantha tetracantha* (Linnaeus)
13. *Alcimosphenus borinquenae* Archer
14. *Cyclosa oculata* (Walckenaer)
15. *Eriophora edax* (Blackwall)

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(*Continued from inside front cover*)

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